JPPIPA 9(12) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Effect STEAM Based Discovery Learning Model on Students Thinking Ability: Meta-Analysis Study

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Received: October 10, 2023
Revised: November 1, 2023
Accepted: December 25, 2023
Published: December 31, 2023

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DOI: 10.29303/jppipa.v9i12.5944

Abstract: This study aims to determine the effect of the STEAM-based discivery learning model on students' critical thinking skills. This research is a type of meta-analysis research. The researchsample came from 17 national and international journals. Samples were obtained through databases in the journals Springer, Wiley, ScienceDirect, Google Scholar, Taylor of Francis, SAGE, and the Education Resources Information Center (ERIC). The inclusion criteria are research published in 2019-2023; The study had experimental and control classes, journals had to be indexed Science and Technology Index (SINTA), Scopus, and Web of Science (WOS) and the sample size in this study was 1,078 students. Data analysis calculated the value of summary effect size, heterogeneity test and publication bias with JASP 0.8.0.4 application. These results conclude that the summary effect size value (rE = 0.902; p < 0.001) then this result shows that the STEAM-based discovery learning model has a positive effect on students' critical thinking skills at high criteria. This finding shows that the application of the STEAM-based discovery learning model has a significant influence on students' critical thinking skills in learning at school.

Keywords: Critical thinking; Discovery learning; Meta-analysis; STEAM

Introduction

The ability to think critically is an ability that students must master in facing the industrial revolution 4.0 (Sutoyo et al., 2023; Orhan, 2023; Kizilhan, 2022). Critical thinking is a process of thinking systematically and logically to solve a problem (Huang et al., 2022;Elfira et al., 2023; Suharyat et al., 2023; Patandung, 2023). Critical thinking skills are very important to be developed to train students' reasoning in analyzing, reconstructing andmaking decisions (Nugraha et al., 2017; Suryawan et al., 2023; Algouzi et al., 2023). Yousef (2021) explained that the ability to think helps students be more active and creative in the learning process. In addition, critical thinking skills help students analyze a problem faster (Ariani, 2020; Putra et al., 2023; Temel, 2022).

But in reality, students' critical thinking skills in Indonesia are still relatively low (Astika et al., 2013; Maison, 2022). This result can be seen in the 2018 *Programme Internationale for Student Assessment* (PISA) research conducted by the OECD that students' science literacy in critical thinking is relatively low, only obtaining a score of 396, ranking 71 out of 78 participating countries (Utomo et al., 2023; Suryono et al., 2023; Oktarina et al., 2021; Zulyusri et al., 2023). In addition, the results of the *Trends in International Mathematics and Science Study* (TIMSS) study in 2015 stated that the critical thinking ability of Indonesian students obtained a score of 391 far lower than the average International score of 500 (Luciana et al., 2023;

How to Cite:
Kadir, D., Judijanto, L., Widodo,. J., Sidik. E. A., Haq, M. S., & Santosa, T. A. (2023). The Effect STEAM Based Discovery Learning Model on Students Thinking Ability: Meta-Analysis Study. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 1245–1253. https://doi.org/10.29303/jppipa.v9i12.5944

Rahman et al., 2023; Nurtamam et al., 2023). In addition, students' low critical thinking skills are influenced by many factors, one of which is the selection of inappropriate learning models that encourage students to think critically (Farizi et al., 2019; Ramdani, 2016; Al-fikry & Shukri, 2018)

The discovery learning model is one of the learning models that can encourage students' critical thinking skills (Ristanto et al., 2022; Hariyanto et al., 2022; Eskris, 2021). Discovery learning is a learning model that leads students to be more active and creative in finding concepts and theories by themselves (Usman et al., 2022; Hariyanto et al., 2023; Winarni, 2020). Dina et al., (2019) explained that the discovery learning model leads students to discover new concepts in learning. The *discovery learning* model of students discovering new things through an experiment to draw a conclusion (Chusni et al., 2020; Komariyah & Karimah, 2019; Permatasari et al., 2018).

Furthermore, the discovery learning model can be combined with STEAM. STEAM is a learning approach that combines Science Technology Engineering Arts and Mathematic in the learning process (Edelen et al., 2023; Ng et al., 2022; Konkuş & Topsakal, 2022). STEAM learning trains students to be scientific, innovative and more familiar with technology to solve a problem (Özer & Demirbatır, 2023). Cobos et al., (2023) explain that this STEAM approach can encourage students' curiosity and motivation in higher-order thinking. Therefore, the discovery leaning model is very suitable combined with STEAM.

Research Surur et al. (2019), Widiadnyana et al. (2014), Sinambela et al. (2018) discovery learning model can improve students' understanding of concepts and scientific attitudes in learning. Research Rahmayani et al. (2019), Suendarti (2017) explain that *discovery* learning models can improve student learning outcomes. Furthermore, research from outside Indonesia (Gutiérrez et al., 2022; Veermans et al., 2000) the discovery learning model can encourage students to be more active and independent in finding concepts or subject matter. The gap in this study, there is a lot of research on discovery learning models but there is no STEAM-based meta-analysis of the STEAM-based dsicover learning model on students' critical thinking skills. Therefore, this study aims to influence the STEAM-based discivery learning model on students' critical thinking skills.

Method

This research is a type of meta-analysis research. Meta-analysis is a study that collects and analyzes quantitative data statistically (Balemen, 2018; Juandi et al., 2022; Razak et al., 2021; Rahman et al., 2023; Diah et al., 2022; Öztürk et al., 2022). Data samples in this study came from 17 national and international journals. Samples were obtained through databases in the journals Springer, Wiley, ScienceDirect, Google Scholar, Taylor of Francis, SAGE, and the *Education Resources Information Center* (ERIC). The inclusion criteria are research published in 2019-2023; Research has experimental and control classes, research related to STEAM-based discovery learning mode on students' critical thinking skills, journals must be indexed Science and Technology Index (SINTA), Scopus, and Web of Science (WOS) and the sample size in this study is 1,078 students.

Furthermore, the data selection process using the *Preferred Reporting Items for Systematic Reviews and Meta-Analysis* (PRISMA) method can be seen in Figure 1. According to Borenstein et al. (2007), the steps in meta-analysis research are formulating a research problem; collect data; perform data encoding; analyze and interpret data. Analysis Analysis data calculates the value of summary effect size, heterogeneity test and publication bias with JASP 0.8.0.4 application. For the criteria of effect size values guided by criteria (Cohen, 2007) can be seen Table 1.

Table 1. Effect Size Value Criteria (Cohen et al., 2007)

Effect Size	Criterion
0.00 < ES < 0.20	Low
0.20 < ES < 0.80	Moderate
ES ≥ 0.80	High

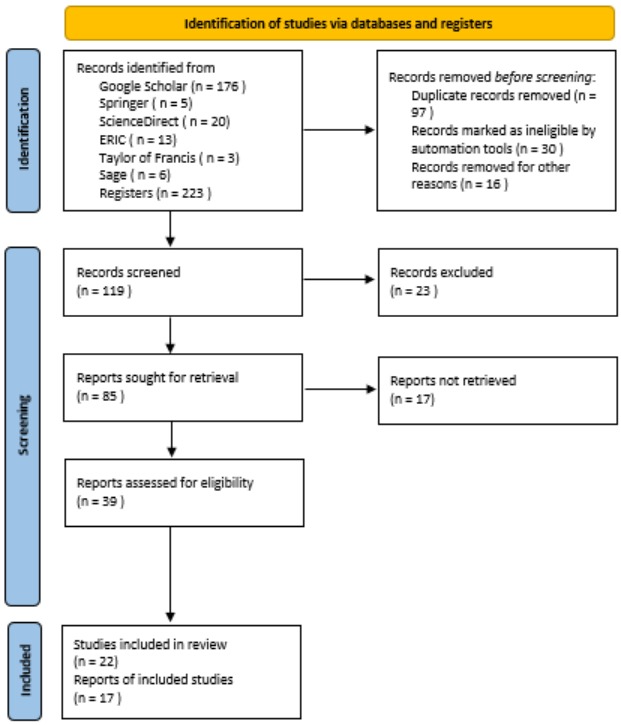

Figure 1. Data selection using PRISMA method

Result and Discussion

Results

From a search of 223 studies obtained from the Springer, Wiley, ScienceDirect, Google Scholar, Taylor of Francis, SAGE, and Education *Resources Information Center* (ERIC) databases related to the STEAM-based discovery learning model on students' critical thinking skills, only 17 studies were obtained that met the inclusion criteria. Research samples that have met the inclusion criteria are analyzed based on journal code, year of publication, Country, sample size, Journal Index and Effect Size. The results of the analysis of the research sample can be seen in Table 2.

Table 2. Analysis of Research Samples Based on Inclusion Criteria

Journal Code	Year of Publication	Country	Journal Index	N	Effect Size	Criterion
AP1	2020	Indonesian	Sinta	120	2.08	High
AP2	2020	China	Scopus	346	0.94	High
AP3	2022	China	Wos	100	1.28	High
AP4	2021	Egypt	Wos	86	0.86	High
AP5	2021	Indonesian	Scopus	210	1.10	High
AP6	2021	India	Scopus	90	1.07	High
AP7	2023	Turkish	Wos	130	2.15	High
AP8	2021	Turkish	Scopus	318	0.90	High
AP9	2022	Indonesian	Sinta	80	1.12	High
AP10	2023	Indonesian	Sinta	40	0.64	Moderate
AP11	2019	Turkish	Scopus	180	0.81	High
AP12	2019	Indonesian	Sinta	30	0.15	Low
AP13	2020	Indonesian	Sinta	48	0.94	High
AP14	2023	United States	Scopus	110	1.03	High
AP15	2020	Indonesian	Sinta	64	0.91	High
AP16	2022	Indonesian	Sinta	38	0.72	Moderate
AP17	2021	China	Scopus	90	0.96	High

Based on Table 2. Showing the analysis of published research samples from 2019-2023 indexed by Scopus, WOS and SINTA, research comes from countries (Indonesia, Turkey, China, Egypt, United States), sample size (N) ranges from 30-346 students. Furthermore, one study of effect size value of 0.15 low criteria, two studies of effect size criteria ranging from 0.64–0.72 medium criteria, and fourteen studies of effect size values ranging from 0.81–2.18 high criteria. The next step is to conduct research heterogeneation tests and selection of estimation models. The results of the heterogeneity test can be seen in Table 3.

Table 3. Heterogeneity Test Results

	Q	Df	p
Omnibus Test of Model Coefficient	45.804	16	0.001
Test of Residual Heterogeneity	26.170	1	0.001

Based on Table 3 explaining heterogeneity test values (Q = 45.804; p < 0.001) then the study is heterogeneously distributed. Therefore, the meta-analysis model used in this study is *a random effect model*. The next step, determine publication bias. Analysis of the publication bais in this meta-analysis with funnel plot diagrams. The results of the publication bias analysis using funnel flot can be seen in figure 2.

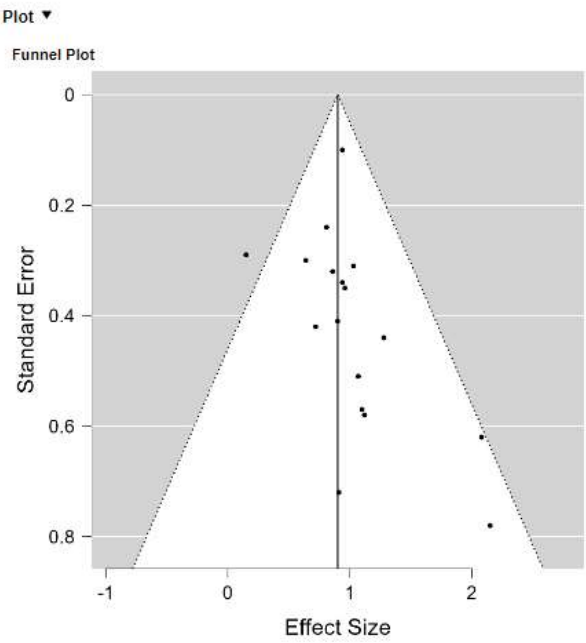

Figure 2. Standard funnel plot error

Based on Figure 2, explaining the analysis of effect size withfunnel flot, it is not yet clearly known the symmetrical or asymmetric shape. Effect sizes are not entirely within the vertical lines of the chart. Therefore, it is necessary to perform the *Roshintal Fail safe* N (FSN)

test. Roshintal Fail safe N (FSN) test results can be seen in Table 4.

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

File Drawer Analysis	Fail Safe N	Target Significance	Observed Significance
Rosenthal	803.00	0.050	<.001

Table 4, applying the *Rosenthal fail safe* N (FSN) test value of (803.00; $p < 0.001$) then in this study the effect size is asymmetric. Furthermore, the value of 803 / (5.17) + 10 = 803 / 95 = 8.45 > 1 means that in this study there is no publication bias. The next step is to calculate the summary effect size value to see the effect of the STEAM-based discovery learning model on students' critical thinking skills. The summary effect size test results can be seen in Table 5.

Table 5. Summary Effect Size Coefficients

	Estimate	Standard Error	z	p	95% Confidence Interval Lower	Upper
intercept	0.902	0.069	13.078	<.001	0.767	1.037

Note. Wald test.

Based on Table 5, explains that the summary effect size value ($r_E = 0.902$; $Z = 13.078$; $p < 0.001$). These results conclude that the STEAM-based discovery learning model has a positive effect on students' critical thinking skills. The findings show that the application of the STEAM-based discovery learning model has a high influence on students' critical thinking skills.

Discussion

From the analysis of 17 studies related to the STEAM-based discovery learning model on the critical thinking skills of students who have met the inclusion criteria, it shows that the STEAM-based discovery learning model has a significant influence on students' critical thinking skills. This result can be seen from the summary effect size value ($r_E = 0.902$) with high influence criteria. Research Andayani (2020) and Prahani et al. (2021), the discovery learning model has an influence on students' critical thinking skills in carrying out the learning process. The STEAM-based Discovery learning model can train students to be more active and innovative in discovering learning concepts by themselves (Noer, 2018; Syolendra & Laksono, 2019; Mardi et al., 2021). Furthermore, the application of the discovery learning model is student-oriented so that it can stimulate critical thinking skills in learning (Aldalur & Perez, 2023).

Sawah et al. (2023) explained that the disvovery learning model can foster student interest and motivation which can encourage critical thinking skills in the learning process. The STEAM-based *Discovery learning* model can help students find theories and concepts through an experiment through technology (Zahara et al., 2020; İlhan & Gulersoy, 2019; Wardono et al., 2020; Piila & Salmi, 2021; Kristanto, 2023). STEAM-based learning trains students in mastering science and technology to solve a problem (Wittayakhom & Piriyasurawong, 2020; Rüütmann, 2022). Research Frediana et al. (2021), and Anito Morales (2019) STEAM learning can improve students' creative and critical thinking in making decisions.

Research Abdullah et al. (2022), Sukartiningsih et al. (2019), and Tompo et al. (2016), the discovery learning model develops active and independent student engagement so as to stimulate students to think critically. Critical thinking skills are very important for students in analyzing and assessing learning material. Temel (2022) critical thinking skills play an important role in solving a student problem in learning. Furthermore, critical thinking skills need to be encouraged so that students can think logically in drawing a conclusion (Morais et al., 2023; Vachova et al., 2023). Therefore, the existence of a STEAM-based discovery learning model provides a solution for teachers in encouraging students' critical thinking skills in schools.

Conclusion

From this study, it can be concluded that the summary effect size value ($rE = 0.902$; $p < 0.001$) then these results show that the STEAM-based discovery learning model has a positive effect on students' critical thinking skills on high criteria. This finding shows that the application of the STEAM-based discovery learning model has a significant influence on students' critical thinking skills in learning at school. The STEAM-based discovery learning model helps students better understand science and technology to solve a problem.

Acknowledgments

We would like to thank all researchers who have been involved in compiling and completing this research. Not only that, we would like to thank the JPPIPA editorial board for being willing to publish this article.

Author Contributions

In this research, all authors Dalimawaty Kadir, Loso Judijanto, Joko Widodo, Ellfi Alfiani Sidik, Muhammah Syahidul Haq, and Tomi Apra Santosa contributed to completing this article starting from data collection, data filtering, data analysis and interpretation to complete this article.

Funding
This research declares no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

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