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Systematic Literature Review and Meta-Analysis: The Effectiveness of Project-Based Learning in Science Learning

Lusy Tunik Muharlisiani[1*], Susantinah Nugrahini Wisnujati[1], Titik Purwati[2], Kartini Marzuki[3], Bachtiar Nasution[4], Tomi Apra Santosa[5]

[1] Universitas Wijaya Kusuma Surabaya, Surabaya, Indonesia.
[2] IKIP Budi Utomo, Surabaya, Indonesia.
[3] Universitas Negeri Makassar, Makassar, Indonesia.
[4] Universitas Asahan, Medan, Indonesia.
[5] Akademi Tekni Adikarya, Jambi, Indonesia.

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Corresponding Author:
Lusy Tunik Muharlisiani
lusytm_fbs@uwks.ac.id

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Abstract: This study aims to determine the effectiveness of the project-based learning model in science learning. This type of research is systematic literature review (SLR) research and meta-analysis. The source of data in this study came from 653 articles obtained 24 articles that met the criteria. The process of searching for data sources comes from the databases of google scholar, Taylor of Francis, Wley, ERIC, and ScienceDirect. Data selection process with PRISMA method. The inclusion criteria in this meta-analysis are that research must come from Scopus indexed journals and Science and Technology Index (SINTA), Research published from 2020-2023, Research must have an experimental class of project based learning models and conventional learning control classes, research must have complete data to calculate the value of effect size. Analyze data with the help of JSAP applications. The results concluded that the summary effect value or mean effect size was 0.86 with large criteria. This finding is that the project-based learning model can improve students' science learning ability.

Keywords: Effect size; Meta-analysis; Project based learning; Science; Systematics literature review

Introduction

Science learning is a subject that trains students to think logically and scientifically in learning (Ariani, 2020; Permatasari et al., 2019). Science learning helps students learn directly with nature (Amin et al., 2020; Suhaimi et al., 2022; Uluçinar, 2023). In the science learning process, students are able to think critically in solving a problem in life (Aidoo & Ofori, 2016; Hugerat et al., 2021; Suendarti & Virgana, 2022; Dharma et al., 2019). In addition, science learning leads students to learn nature creatively and innovatively (Tiarini et al., 2019),so that students get information for learning resources. Science learning provides direct experience to students in developing complexity through the universe scientifically (Ayu et al., 2019; Han & Shim, 2023; Angganing et al., 2022).

Science learning currently in schools has many problems, especially student learning outcomes are relatively low (Utami & Astawan, 2020; Astuti et al., 2020), students' critical thinking and problem-solving skills are still relatively low (Elfira et al., 2023; Ichsan et al., 2023; Anazifa & Djukri, 2017; Hariyadi et al., 2023; Hestiana & Rosana, 2020; Sihaloho et al., 2017). In the science learning process, it is too teacher-centered so that students find it difficult to understand the material (Annisa et al., 2022). In addition, classroom learning does not involve active and innovative students in learning (Rahman et al., 2023; Puspita et al., 2023). This result is also supported by the *Programme for International Student Assessment* (PISA) research

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conducted by the OECD In 2018, the results of Indonesian students' science literacy were relatively low, only obtaining a score of 396, ranking 71 out of 78 countries (Utomo et al., 2023; Zulkifli et al., 2022; Sofianora et al., 2023; Razak et al., 2021). The low quality of student science learning is also influenced by the selection of learning models that teachers do not are appropriate (Hutabarat et al., 2018; Sulastri & Pertiwi, 2020).

Project-based learning is an effective learning model used in science learning (Hutapea & Simanjuntak, 2017; Fahrezi et al., 2020; Çakici & Türkmen, 2013). Project-based learning is a learning model that guides students to produce a product in the learning process (Safaruddin et al., 2020; Lazic, 2021; Asfihana, 2022; Kiliç, 2022; Viro et al., 2020). Project Based Learning helps students learn more actively and creatively in solving a problem (Kiliç, 2023). According to Payoungkiattikun et al., (2022) *project based learning* trains students to work together in groups.

Project based learning model research has a significant influence on students' creative thinking skills (Mursid et al., 2022; Sumarni & Kadarwati, 2020; Suryandari et al., 2021; Mihardi et al., 2013). Project-based learning has a positive effect on students' critical thinking and problem-solving skills (Astra et al., 2019; Saripudin et al., 2015; Parvati et al., 2019; Mutakinati & Anwari, 2018). However, research by Tempera et al. (2023) and Lim et al. (2023) explain inconsistent results. Applied research tests, project-based learning is not effective, compared to conventional models. Therefore, research finds different results have an impact on making a decision in science learning (Wuttphan & Klinhom, 2023). So, to fill a gap in it is necessary to find concrete information in drawing a conclusion. Therefore, it is necessary to conduct meta-analysis research aimed at determining the effectiveness of the project-based learning model in science learning.

Method

This research is a type of meta-analysis research. Meta-analysis research serves to determine the effectiveness of the project-based learning model in science learning. Meta-analysis is a type of research that analyzes quantitative data from primary studies (Yıldırım, 2022; Öztürk et al., 2022; Santosa et al., 2021; Luciana, 2023; Kaçar et al., 2021).

Data Collection

Data collection through the database of google scholar journals, Taylor of Francis, Wley, ERIC, and ScienceDirect. Search keywords are project based learning, science learning, the influence of *project based* learning in science learning. The data selection process is carried out through the PRISMA method consisting of *identification, screening, eligibility* and *inclusion* can be seen in figure 1.

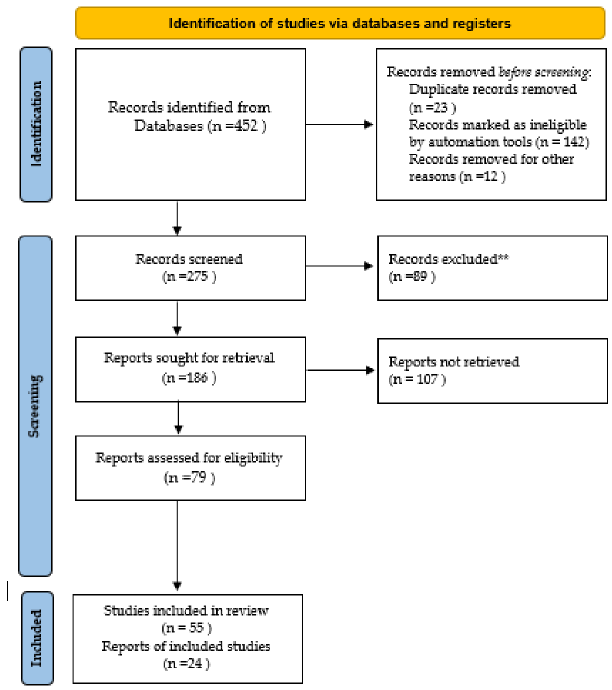

Figure 1. Data selection with PRISMA

Inclusion Criteria

The inclusion criteria in this study consist of publications published in 2020-2023; research must be experimental methods or Quasi-Experiments; Research indexed by SINTA and Scopus, Research related to project-based learning and science learning and research must report complete data to calculate effect size.

Data Coding

Data coding in meta-analysis is very important to make it easier to analyze data (Diah et al., 2022; Chamdani et al., 2022). Data coding is done by the researchers themselves. Data coding describes the characteristics of research consisting of authors; year of publication, effect size and Standard error (SE).

Data Analysis

Data analysis techniques in this meta-analysis consist of 1) calculating the effect size value of the primary study; 2) testing publication bias and determination of estimation models; 3) check publication bias and 4) calculate p-values to test hypotheses (Borenstein et al., 2009; Joseph, 2023) can be seen (Figure 2). Data analysis was performed with the help of JSAP 0.8.4.0 software. The effect size criteria to determine the effect of project-based learning in science learning are guided by the effect size Cohen et al. (2007) can be seen in Table 1.

Table 1. Cohen's Effect Size Value Criteria

Effect Size	Category
0.00 ≤ ES ≤ 0.20	Small
0.20 ≤ ES ≤ 0.80	Medium
ES ≥0.80	Large

Publication Bias

Publication bias is often considered a common challenge faced by researchers in meta-analysis studies (Aybirdi, 2023). This challenge arises from the habit of choosing research published in well-known journals, focusing on reporting results that show statistical significance. Publication bias checking was analyzed with funnel plot and Rosenthal fail safe N test (Juandi et al., 2022; Dochy et al., 2003; Tamur et al., 2021).

Result and Discussion

Results From a search of the Google Scholar database, Taylor of Francis, Wley, ERIC, and ScienceDirect obtained 24 journals that met the inclusion criteria. Journals that meet the criteria are calculated effect size values which can be seen in Table 2.

Table 2. Effect Size 24 Journal

Journal Code	Journal Index	Year	Effect Size	Country
JR1	Sinta	2022	2.12	Indonesian
JR2	Sinta	2021	0.89	Indonesian
JR3	Scopus	2023	1.21	Malaysia
JR4	Sinta	2020	0.18	Indonesian
JR5	Scopus	2022	0.52	India
JR6	Sinta	2021	0.45	India
JR7	Scopus	2021	0.92	Spanish
JR8	Scopus	2023	2.20	English
JR9	Scopus	2023	1.52	Turkish
JR10	Sinta	2021	0.83	Indonesian
JR11	Scopus	2020	0.39	Chinese
JR12	Scopus	2023	0.71	Chinese
JR13	Sinta	2023	0.83	Indonesian
JR14	Sinta	2022	0.90	Indonesian
JR15	Sinta	2021	1.08	Indonesian
JR16	Sopus	2022	1.32	Portugal
JR17	Scopus	2021	0.51	Pakistan
JR18	Sinta	2020	1.14	Indonesian
JR19	Scopus	2020	0.95	Chile
JR20	Sinta	2020	1.14	Indonesian
JR21	Sinta	2023	0.73	Indonesian
JR22	Scopus	2023	0.62	Chinese
JR23	Sinta	2022	0.91	Indonesian
JR24	Sinta	2021	0.77	Indonesian

Based on Table 2, the results of effect size analysis from 24 studies analyzed obtained effect size values ranging from 0. 39 equals 2.20. According to the effect size criteria Cohen et al. (2007) there is one small category effect size (4.17%), two medium category effect sizes (8.33%) and twenty-one large category effect sizes (87.50%) (Cohen et al., 2007). Next, test the heterogeneity of journals that have met the inclusion criteria. The results of the heterogeneity test can be seen in Table 3.

Table 3. Heterogeneity Test Results

	Q	Df	p
Model Coefficient omnibus test	289.110	1	< 0.001
Residual Heterogeneity Test	67.072	23	< 0.001

Note. the p value is approximate

Table 3, explaining the results of the heterogeneity test of twenty-four effect sizes analyzed obtained a value of Q = 289,110 greater than the value of 67,072 then the effect size analyzed is heterogeneously distributed. Next, check the publication bias of the 24 journals analyzed. Publication bias checking serves to determine the validity of the data analyzed in the meta-analysis (Martin & Carolina, 2022; Çevik & Bakioğlu, 2022; Nurhayati et al., 2023). Data publication bias occurs due to significant and positive unpublished research data (Baysal et al., 2023), then the effect size value becomes high (Borenstein et al., 2010; Baysal et al., 2023; Borenstein et al., 2010). Publication bias checking can be known through funnel plot analysis and Rosental Fail Safe N test (Li & Wang, 2023; Vo et al., 2017). The results of the funnel plot analysis of twenty-four effect sizes are shown in figure 2.

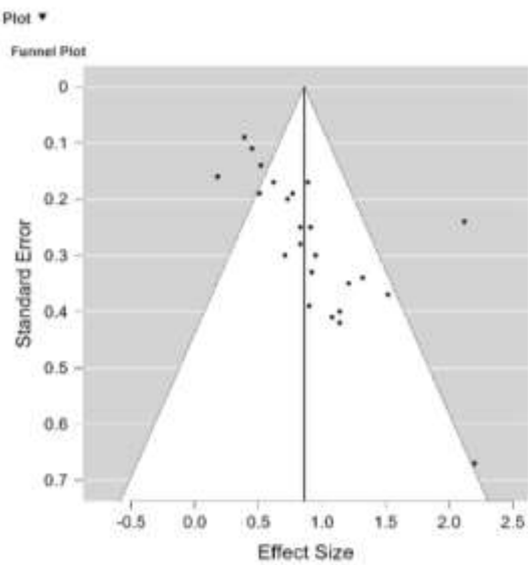

Figure 2. Funnel Plot

Based on figure 2, publication bias analysis with funnel flot is still difficult to know whether the curve is symmetrical or asymmetric. Therefore, it is necessary to do an Egger's test to determine the shape of the effect size curve on the funnel plot. Egger's test results can be seen in Table 4.

Table 4. Egger's Test Results

	z	p
Sei	4.094	< 0.001

Based on Table 4, Egger's test results obtained values (Z = 4.094; p < 0.001), then the curve is symmetrical. Furthermore, to increase the validity of the data on the 24 journals analyzed, it is necessary to check publication bias through Rosenthal Fasil Safe N (FSN). Rosenthal fail safe N (FSN) test results can be seen in Table 5.

Table 5. Safe N File Test Results

	Secure fail N	Target Significance	Observed significance
Rosenthal	2367	0.050	< 0.001

Based on Table 5 Rosenthal *fail safe* N (FSN) test result of 2367. Next, the FSN value is entered in the formula k = (5.24) + 10 = 130. The results can be concluded FSN value > 130, meaning that in the study there is no publication bias. Finally, analyze the *summary* effect size or mean effect size to determine the effectiveness of *the project-based* learning model in science learning. The results of the summary effect size test can be seen in Table 6.

Table 6. Effect Size Summary

	Estimated	Standard Error	z	p	Lower limit	Upper limit
Intercept	0.86	0.28	9.10	< 0.001	0.71	1.03

Based on Table 6, the summary effect size value is obtained (Z = 9.106; P < 0.001) with a confidence level of 95% lower 0.71 and upper 1.03. Next, the mean effect size value (r_{RE} = 0.86; SE = 0.28) large category. This finding concludes that the application of the project-based learning model has a positive influence with a large category in science teaching.

This research is in line with Nurhidayah et al., (2021) Project Based Learning has a positive influence on science learning. These findings are supported by Çakici et al. (2013) project based learning model can offer student achievement and scientific attitude in learning. Project-based learning encourages students to learn more actively and innovatively to produce a product in science learning (Kızkapan, 2017; Kubiatko, 2014). Project-based learning can help students think creatively to solve a problem in life (Lestari & Sumarti, 2018; Lazic, 2021; Aho & Wright, 2020). In addition, project-based learning is able to improve students' science learning outcomes (Jagantara et al., 2014; Asfihana, 2022).

The project-based learning model helps students be more active in solving a problem (Kiliç, 2022). Not only that, the application of project-based learning can improve students' higher-order thinking skills in science learning (Özkan, 2023; Niswara et al., 2019; Issa et al., 2021). Science learning is guided by students to apply scientific methods and attitudes in learning (Tang & Zhang, 2020). Therefore, the application of the project-based learning model provides solutions for teachers to improve students' knowledge, affectives and psychotors in learning science.

Conclusion

In this meta-analysis study, it can be concluded that the summary effect value or mean effect size is 0.860 with high criteria. This finding is that the project-based learning model can improve students' science learning ability. Project-based learning encourages students to think creatively and innovatively to produce a product to solve a problem in PA. The application of project-based learning can develop students' knowledge and skills in science learning.

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Conflicts of Interest
The authors declare no conflict of interest.

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