Meta-Analysis: Comparative Effect of Project-Based Learning and Problem-Based Learning on Scientific Literacy Skills in Science Learning

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ABSTRACT

The low level of science literacy among Indonesian students in PISA is a major concern, highlighting the need for innovative learning models such as Project-Based Learning (PjBL) and Problem-Based Learning (PBL). However, the comparative effectiveness of these two models has not yet been extensively synthesized quantitatively. This study aims to compare the effects of PjBL and PBL on high school students' science literacy in science education using a meta-analysis approach. This meta-analysis follows the PRISMA 2020 protocol, with a literature search conducted across five databases (Google Scholar, ResearchGate, ERIC, ScienceDirect, and Portal Garuda) covering the period 2016–2026. Inclusion criteria included: a population of high school students; PjBL or PBL interventions; experimental designs with control groups; and the availability of complete statistical data (mean, SD, n, or t-values). Effect sizes were calculated using Hedges' g with a random-effects model. A total of 14 studies met the inclusion criteria (10 PBL studies and 4 PjBL studies). The average effect size for PBL was 1.76 (very large category) with high heterogeneity (I^2 = 91.45%). The average effect size for PjBL was 0.77 (large category) with low heterogeneity (I^2 = 0%). The difference in effect size between PBL and PjBL, which was 0.99 points, indicates the quantitative superiority of PBL. The PBL model proved to be more effective than PjBL in improving high school students' science literacy. It is recommended that teachers prioritize PBL, while the implementation of PjBL should be designed with a stronger emphasis on scientific inquiry.

Keywords: Meta-analysis, Project-Based Learning, Problem-Based Learning, Scientific Literacy, Science Learning

INTRODUCTION

Science literacy is an essential 21st-century competency that encompasses the ability to explain scientific phenomena, evaluate investigations, and interpret data (OECD, 2019; Sholikah & Pertiwi, 2021). However, Indonesian students' science literacy scores on PISA remain relatively low and have tended to stagnate (Hamzah et al., 2023; Putri et al., 2025). The dominance of conventional, teacher-centered learning is one of the root causes of the problem, as it leaves little room for the development of active science process skills (Alam, 2016; Kalengkongan et al., 2025). As a solution, the Project-Based Learning (PjBL) and Problem-Based

Learning (PBL) models are often recommended because both are grounded in constructivism and oriented toward authentic problem-solving (Ali, 2026; Ridani & Arianingrum, 2024).

Over the past five years, various primary studies have examined the effects of PjBL and PBL on science literacy separately. Winarni & Koto (2020) reported that the implementation of PjBL through the development of student activity sheets significantly improved science literacy in science courses. Another study by Yudiana et al. (2025) also showed that a PjBL approach integrated with STEM in science education is effective in improving students' science literacy and critical thinking skills. Meanwhile, regarding PBL, Yolida et al. (2021) found that a Vee-diagram-assisted PBL model effectively improved students' science literacy on the topic of environmental pollution. Astawan et al. (2025) reported that a PBL model oriented toward Balinese local wisdom had a significant impact on improving science literacy, particularly among students with a reflective cognitive style. Nevertheless, these studies are standalone and were not designed to directly compare the effectiveness of PjBL versus PBL.

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Although PjBL and PBL have been extensively studied, the results of primary studies show quite striking inconsistencies. Aini (2022) found significant differences in the effects of PBL and PjBL implementation on science literacy, with a t-test showing a significance value of $0.029 < 0.05$, while Suryani (2016) reported that, in general, there were no significant differences between the two models ($\alpha = 0.05$) in improving students' science literacy skills, except for the sub-aspect of the ability to explain natural phenomena. Furthermore, a study by Dianti & Indarini (2025) confirmed that PBL consistently has a positive effect on improving students' science literacy. The inconsistency of these findings indicates that there is still no consensus within the academic community regarding which model is more effective, while also highlighting the need for a more systematic quantitative synthesis.

Although problem-based learning (PBL) and project-based learning (PjBL) are widely recommended for improving students' science literacy, the empirical evidence base in Indonesia still has significant gaps. As of 2026, there has been no comparative meta-analysis that systematically compares the effects of PBL versus PjBL on science literacy in Indonesia. Previous meta-analyses have focused only on one model in isolation for example, PBL (Ali, 2026) or PjBL (Muharlisiani et al., 2023) or within the context of STEM-integrated models (Arisujarnata et al., 2025). Other studies have also placed greater emphasis on general cognitive learning outcomes (Azmi & Mufit, 2021), rather than specific science literacy constructs such as explaining scientific phenomena, evaluating investigations, or interpreting evidence-based data. Furthermore, the emergence of various new primary studies between 2024 and 2026 such as those examining the effectiveness of PBL (Nikmatusyadiah & Yerimadesi, 2026) and PjBL (Lubis et al., 2026) in diverse local contexts reinforces the urgency of a more comprehensive data synthesis. However, since there has been no meta-analysis to date that directly compares the two models, such research has become particularly urgent in 2026 to fill this research gap and provide evidence-based guidance for teachers and policymakers in the implementation of the Merdeka Curriculum.

This meta-analysis serves as a solution to address the fragmentation and inconsistencies found in primary studies. Its novelty lies in the integration of quantitative data from various studies to objectively and comprehensively calculate and compare the pooled effect size (Borenstein et al., 2009; Cooper et al., 2019; Glass, 1976). This approach increases statistical power and allows for generalizations beyond the limitations of individual samples (Retnawati et al., 2018). Its practical contribution for science teachers is to provide evidence-based recommendations, while for policymakers, the results of this meta-analysis can serve as a foundation for curriculum development and teacher training. Based on the above discussion, the primary objective of this meta-analysis article is to quantitatively compare the effects of PjBL and PBL on students' science literacy skills in science education. Specifically, this study aims to calculate the combined effect size of each model and to test whether there are significant differences between the two. The results of this meta-analysis are expected to provide definitive conclusions regarding which model is more effective and under what conditions each model works optimally.

METHOD

This study is a quantitative meta-analysis with a two-group independent comparative design that compares the effects of Project-Based Learning (PjBL) and Problem-Based Learning (PBL) on high school students' science literacy in science education. A meta-analysis was chosen because it can combine the results of various heterogeneous primary studies to produce a more precise aggregate effect estimate (Borenstein et al., 2009; Harrer et al., 2022; Page et al., 2021). The research protocol followed the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to ensure transparency, reproducibility, and reduce selection bias (Borenstein et al., 2009; Rethlefsen et al., 2021). Inclusion criteria were established using the PICOS framework: the population of Indonesian high school students; PjBL or PBL interventions; conventional learning as the comparison group; science literacy outcomes; and an experimental design with a pretest-posttest control group (Amir-Behghadami & Janati, 2020; Methley et al., 2014). The publication period was limited to 2016–

2026; only accredited journals (SINTA, Scopus) or international conference proceedings with full-text articles were included. Exclusion criteria include subjects other than high school students, non-science subjects, single-group designs without a control group, and incomplete statistical data (mean, SD, n, or t-values not available) (Page et al., 2021; Schardt et al., 2007).

Data extraction was conducted by the researchers using a standardized form that included study identifiers, sample characteristics, statistical data (pretest-posttest means, SD, n per group, t/F values), and information on the science literacy instruments. The unit of analysis was Hedges' g effect size, which was chosen because it corrects for small-sample bias (Higgins et al., 1981). The effect size for each study was calculated using the formula in the table based on the statistical data that had been collected. Cohen (1988), as cited in Becker & Park (2011), then used the following categories to interpret the effect size data: small effect (0 < ES ≤ 0.2), moderate effect (0.2 < ES ≤ 0.5), large effect (0.5 < ES ≤ 0.8), and very large effect (ES > 0.8).

Tabel 1.:
Effect Size Calculation Formula

No	Given Statistical Data	Formula
1	Mean (X) and standard deviation (SD) on pretest-posttest control group design	$ES = \frac{(\underline{X}_{post-\,exp} - \underline{X}_{pre-\,exp}) - (\underline{X}_{post-\,control} - \underline{X}_{pre-\,control})}{SD_{pooled}}$ where, $SD_{pooled} = \sqrt{\frac{(n_{exp}-1)SD^2{}_{exp}+(n_{control}-)SD^2{}_{control}}{n_{exp}+n_{control}{}^{-2}}}$
2	Mean (X) and standard deviation (SD) on posttest-only control group design	$ES = \frac{\underline{X}_{exp}-\underline{X}_{control}}{SD_{pooled}}$ where, $SD_{pooled} = \sqrt{\frac{(n_{exp}-1)SD^2{}_{exp}+(n_{control}-)SD^2{}_{control}}{n_{exp}+n_{control}{}^{-2}}}$

3	t-test value on posttest-only control group design	$ES = t\sqrt{\frac{1}{n_{eksperimen}} + \frac{1}{n_{kontrol}}}$

In this meta-analysis, the standard error of the effect size (SE) was also calculated using the formula in the table. It is important to calculate both the effect size and the standard error of the effect size in order to test for heterogeneity among studies, determine the mean effect size, and evaluate publication bias. Before calculating the standard error of the effect size (SE), we need to calculate Hedges' g, which is determined using a variance-based approach rather than by directly multiplying the t-value. The first step is to calculate the variance of Cohen's d using the formula.

$$V_d = \frac{n_1 + n_2}{n_1 n_2} + \frac{g^2}{2(n_1 + n_2)}$$

where n_1 and n_2 are the sample sizes of the experimental and control groups, respectively. Next, Cohen's d is corrected to Hedges' g using the bias correction factor:

$$J = 1 - \frac{3}{4(n_1 + n_2 - 2) - 1}$$

Thus,

$$g = d \times J$$

The variance of Hedges' g is obtained from:

$$V_g = V_d \times J^2$$

Finally, the standard error is calculated as the square root of that variance:

$$SE_g = \sqrt{V_g}$$

If a study only reported the t-test statistic for the difference between two groups, the effect size was calculated using:

$$g = t \times \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \times J$$

and the variance and standard error are still calculated following the steps above. Thus, all standard error estimates in this meta-analysis do not depend on reductionist approaches such as

$$SE = t\sqrt{\frac{1}{n_e} + \frac{1}{n_k}}$$

and the variance and standard error were calculated following the steps above. Thus, all standard error estimates in this meta-analysis do not rely on a reductionist approach but follow standard procedures recommended by Borenstein et al. (2009) and Higgins et al. (1981) to ensure the accuracy of confidence intervals and heterogeneity tests.

FINDINGS AND DISCUSSION

The study selection process in this meta-analysis followed the four-stage PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) workflow (Page et al., 2021). A literature search was conducted in five databases Google Scholar, ResearchGate, ERIC (ProQuest), ScienceDirect, and Portal Garuda from January to March 2026. These databases were selected based on their coverage of Indonesia and the international community, as well as their open access policies. Boolean search strings were optimized for each database; for example, on Google Scholar:

"(PjBL OR "Project-Based Learning") AND ("literasi sains" OR "scientific literacy") AND (fisika OR biologi OR kimia) AND (SMA) AND (eksperimen)"

Independent researchers conducted the search and selection to reduce selection bias (Bramer et al., 2017). The initial search yielded 3,980 articles. After removing duplicates (412 articles), 3,568 articles remained. Title and abstract screening by the researchers (Cohen's Kappa = 0.85) left 579 articles. Full-text review and application of the inclusion criteria resulted in 89 experimental articles. Quality assessment using the JBI Checklist for quasi-experimental studies left only 14 articles, consisting of 4 PjBL studies and 10 PBL studies. The mechanistic data from each analyzed study are presented in detail in Table 2 below:

Picture 1:
PRISMA Flowchart

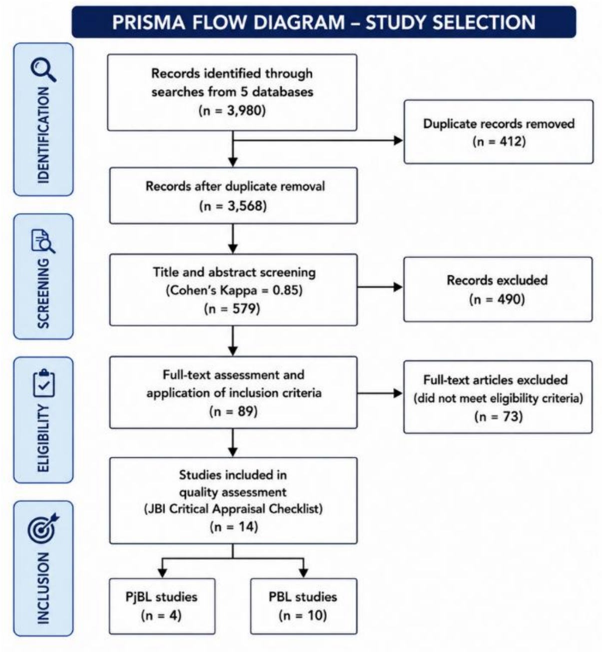


Table 2:
Data Extraction of Characteristics and Effect Sizes from Meta-Analysis Studies

Code	Author(s) & Year	Research Design	Learning Model	Data Provided	ES and Category
P1	(Parno et al., 2020)	Quasi-Experiment (Non-equivalent control group design)	PBL	Experimental class N= 33 $\underline{X}_{pre}$= 43,03 $\underline{X}_{post}$= 68,85 SD_{pre}= 6,59 SD_{post}= 12,90 Control class N= 33 $\underline{X}_{pre}$= 42,15 $\underline{X}_{post}$= 54,33 SD_{pre}= 7,66 SD_{post}= 9,18	ES = 1,297 (Very Large) SE = 0,27
P2	(Sari et al., 2025)	Quasi-Experiment (Pretest-Posttest Control Group)	PBL	Control class N = 94 Experimental class N = 99 $t - value$ = 25,977	ES = 3,74 (Very Large) SE = 0,24
P3	(Nasution et al., 2019)	Quasi-Experiment (Pretest-Posttest Non-equivalent Control Group)	PBL	Control class N = 22 $\underline{X}_{pre}$= 7,58 $\underline{X}_{post}$= 69,73 SD_{pre}= 6,99 SD_{post}= 15,84 Experimental class N = 22 $\underline{X}_{pre}$= 6,73 $\underline{X}_{post}$= 69,73 SD_{pre}= 4,01	ES = 1,33 (Very Large) SE = 0,33

				SD_{post}= 11,17	
P4	(Meidiana & Pertiwi, 2024)	quasi-experiment design control group design	PBL	Control class N = 36 Experimental class N = 36 $t-value$ = 6,638	ES = 1,58 (Very Large) SE = 0,27
P5	(Ramadhanti et al., 2024)	quasi-experiment with the static-group comparison design	PBL	Control class N = 39 $\underline{X}$ = 19,21 SD = 4,03 Experimental class N = 33 $\underline{X}$ = 28,97 SD = 4,32	ES = 2,34 (Very Large) SE = 0,31
P6	(Maulina et al., 2026)	Quasi-Experimental Non-Equivalent Control Group design	PBL	Control class N = 32 $\underline{X}_{pre}$= 75,31 $\underline{X}_{post}$= 80,99 SD_{pre}= 7,57 SD_{post}= 8,11 Experimental class N = 33 $\underline{X}_{pre}$= 69.27 $\underline{X}_{post}$= 82,00 SD_{pre}= 5,19 SD_{post}= 3,30	ES = 1,09 (Very Large) SE = 0,26
P7	(Juleha et al., 2019)	Quasi-Experimental	PBL	Control class N = 20 $\underline{X}_{pre}$= 33,20 $\underline{X}_{post}$= 56,60 SD_{pre}= 10,471	ES = 0,63 (Large) ES = 0,32

				SD_{post}= 13,189 Experimental class N = 19 $\underline{X}_{pre}$= 35,16 $\underline{X}_{post}$= 65,47 SD_{pre}= 11,437 SD_{post}= 14,860	
P8	(Yolida et al., 2021)	Quasi-Experimental Non-Equivalent Control Group design	PBL	Control class N = 34 $\underline{X}_{pre}$= 53,34 $\underline{X}_{post}$= 64,56 SD_{pre}= 6,23 SD_{post}= 5,09 Experimental class N = 34 $\underline{X}_{pre}$= 58,05 $\underline{X}_{post}$= 78,90 SD_{pre}= 6,54 SD_{post}= 5,70	ES = 1,51 (Very Large) SE = 0,27
P9	(Alatas & Fauziah, 2020)	Quasi-Experimental Non-Equivalent Control Group design	PBL	Control class N = 34 $\underline{X}_{pre}$= 43,76 $\underline{X}_{post}$= 60,00 SD_{pre}= 9,69 SD_{post}= 8,69 Experimental class N = 34 $\underline{X}_{pre}$= 42,47 $\underline{X}_{post}$= 81,00 SD_{pre}= 10,88 SD_{post}= 7,32	ES = 2,61 (Very Large) SE = 0,33

P10	(Siregar & Paidi, 2026)	Quasi-Experimental Non-Equivalent Control Group design	PBL	Control class N = 30 $\underline{X}_{pre}$= 55,21 $\underline{X}_{post}$= 58,75 SD_{pre}= 14,43 SD_{post}= 4,81 Experimental class N = 35 $\underline{X}_{pre}$= 55,36 $\underline{X}_{post}$= 77,41 SD_{pre}= 11,02 SD_{post}= 10,25	ES = 1,46 (Very Large) SE = 0,28
Pj1	(Lubis et al., 2026)	Quasi-Experimental Non-Equivalent Control Group design	PjBL	Control class N = 35 $\underline{X}_{pre}$= 54,69 $\underline{X}_{post}$= 66,26 SD_{pre}= 9,719 SD_{post}= 3,020 Experimental class N = 35 $\underline{X}_{pre}$= 59,51 $\underline{X}_{post}$= 82,23 SD_{pre}= 11,680 SD_{post}= 3,175	ES = 1,04 (Very Large) ES = 0,25
Pj2	(Balqis et al., 2025)	Quasi-Experimental Non-Equivalent Control Group design	PjBL	Control class N = 37 $\underline{X}_{pre}$= 47 $\underline{X}_{post}$= 67 SD_{pre}= 20,28 SD_{post}= 21,20 Experimental class	ES = 0,56 (Large) ES = 0,23

				N = 37 $\underline{X}_{pre}$= 47 $\underline{X}_{post}$= 79 SD_{pre}= 22,83 SD_{post}= 15,80	
Pj3	(Ayudyaningsih et al., 2024)	quasi-eksperimen	PjBL	Control class N = 39 $\underline{X}$ = 14,43 SD = 5,186 Experimental class N = 33 $\underline{X}$ = 18,43 SD = 5,147	ES = 0, 77 (Large) SE = 0,24
Pj4	(Hidayah & Desnita, 2024)	Quasi-Experimental Non-Equivalent Control Group design	PjBL	Control class N = 36 Experimental class N = 36 $t-value =$ 2,91	ES = 0,69 (Large) SE = 0,24

Based on a meta-analysis of the 14 primary studies in Table 1 that met the inclusion criteria, data on the effect size (ES) of the Problem-Based Learning (PBL) and Project-Based Learning (PjBL) models on science literacy skills in science education were obtained. Ten studies used the PBL model (codes P1–P10) and four studies used the PjBL model (codes Pj1–Pj4). All analyzed studies were quasi-experimental studies employing either a non-equivalent control group design or a pretest-posttest control group design.

The calculated effect sizes for the PBL model showed varying values, ranging from moderate to very large. The highest effect size (ES) for PBL was 3.74 (very large) in study P2, while the lowest was 0.63 (moderate) in study P7. The average effect size across the ten PBL studies was 1.76 (SD = 0.91), which falls into the very large category (Cohen, 1988). The data distribution shows that eight out of ten PBL studies had effect sizes in the large to very large categories, indicating a consistent positive impact of the PBL model on science literacy.

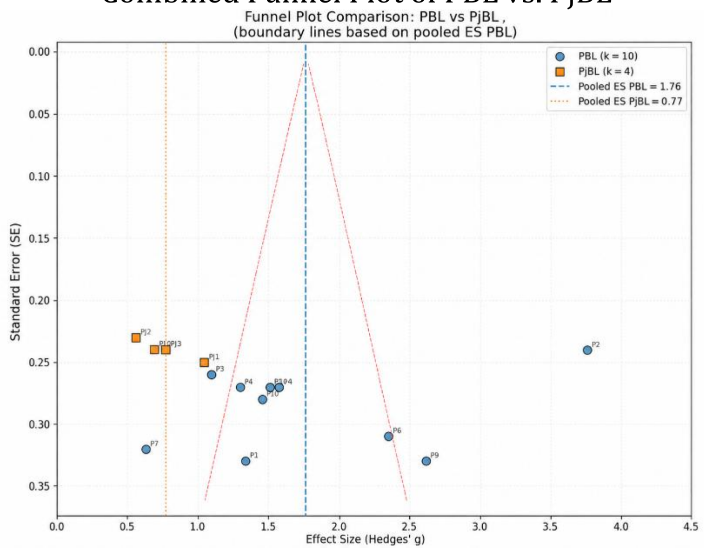
Meanwhile, for the PjBL model, the effect size values ranged from 0.56 to 1.04. The highest ES was 1.04 (large) in study Pj1, and the lowest was 0.56 (medium) in study Pj2. The mean effect size of the four PjBL studies was 0.77 (SD = 0.21), which falls into the large category (Cohen, 1988). Nevertheless, all PjBL studies showed positive effect sizes, indicating that the PjBL model also contributes meaningfully to improving students' scientific literacy skills.

Table 3:
Summary of the Results of the Random-Effects Meta-Analysis for PBL and PjBL

Learning Model	Number of Studies	Mean ES (95% CI)	Q	df	p	I^2 (%)	Kategori
PBL	10	1,76 (1,16-2,36)	105,15	9	<0,001	91,45	Very Large
PjBL	4	0,77 (0,56-1,04)	2,01	3	0,572	0	Large

Based on the statistical summary in Table 4, an interesting comparison between the two learning models was found. The PBL model showed an average effect size of 1.76 with a 95% confidence interval (1.16–2.36), a Q value of 105.15, degrees of freedom (df) = 9, a p-value < 0.001, and I^2 = 91.45% (high heterogeneity category). Meanwhile, the PjBL model showed a mean effect size of 0.77 with a 95% confidence interval (0.56–1.04), a Q value of 2.01, df = 3, a p-value of 0.572, and I^2 = 0% (low heterogeneity category). In a descriptive comparison, the PBL model showed a greater effect on science literacy skills than the PjBL model, with a difference in mean effect size of 0.99 points. These findings indicate the superiority of PBL in the context of improving science literacy in science education.

Picture 2:
Combined Funnel Plot of PBL vs. PjBL



The results of the pooled funnel plot analysis show the distribution of data points from ten PBL studies (k = 10) and four PjBL studies (k = 4) relative to the vertical line representing the pooled effect size of each model (pooled PBL ES = 1.76; pooled PjBL ES = 0.77). Visually, the PBL study data points tend to be asymmetrically distributed around the PBL pooled ES line, with some points falling outside the boundaries of the funnel triangle (particularly studies with small standard errors), indicating potential publication bias or high heterogeneity. The results of the combined funnel plot analysis show the distribution of data points from ten PBL studies (k = 10) and four PjBL studies (k = 4) relative to the vertical line representing the pooled effect size of each model (pooled ES PBL = 1.76; pooled ES PjBL = 0.77). Visually, the PBL study data points tend to be asymmetrically distributed around the PBL pooled ES line, with some points falling outside the boundaries of the funnel triangle (particularly studies with small standard errors), indicating potential publication bias or high heterogeneity.

DISCUSSION

This finding is consistent with research conducted by (Krisdiana et al., 2023) which directly compared the two models on global warming material and found that PBL was superior in improving scientific literacy in the competency aspect (88.5) compared to PjBL (76). Likewise, Aini (2022) in her comparative study reported that the average student learning outcomes in PBL were higher than in PjBL. This difference in effectiveness can be explained through the different cognitive mechanisms of the two models. As stated by Barrows (1986) and Savery (2017), PBL focuses on structured problem-solving that directs students to knowledge elaboration and hypothesis testing systematically.

In contrast, according to Grant (2002) and Thomas (2000) , PjBL emphasizes the creation of a final product that requires a relatively long time, so the intensity of interaction with science content per unit time can be lower than PBL. Hmelo-Silver (2004) and Loyens et al. (2015) also emphasized that in PBL, the scaffolding provided by teachers is more focused on scientific reasoning processes, whereas in PjBL, scaffolding is more distributed to project management and technical skills. This difference causes the depth of science content mastery over the same period to tend to be higher in PBL classes. This is also supported by research by Schmidt et al. (2009) and Azer (2009) which identified that PBL is more effective in developing procedural and epistemic knowledge, which are key components of scientific literacy according to the PISA framework.

The high I^2 value in the PBL group (91.45%) indicates substantial heterogeneity among studies, meaning that the variation in effect sizes is not solely due to sampling error but also due to differences in study characteristics such as educational level, learning material, intervention duration, and scientific literacy measurement instruments used. This finding aligns with Higgins et al. (2003) and Borenstein et al. (2021), who stated that $I^2 > 75\%$ indicates high heterogeneity and requires moderator analysis to identify sources of variation. The I^2 value in the PjBL group (0%) indicates that all variation among studies is due to sampling error, and those studies are relatively homogeneous. According to Deeks et al. (2019) and Huedo-Medina et al. (2006), an I^2 value of 0% indicates that all studies in the group measure similar constructs with consistent methodological characteristics.

The high heterogeneity in the PBL group can be explained by variations in moderator factors such as the type of science material (physics, biology, or chemistry), duration of learning model implementation, and sample characteristics such as initial ability level, sample size, and socioeconomic background. Lipsey & Wilson (2001) and Hunter & Schmidt (2004) emphasize that identifying moderator factors is an important step in meta-analysis to understand the conditions that maximize intervention effectiveness. Pigott (2012) also added that high heterogeneity is not always a weakness but can be an opportunity to explore variables that moderate the effectiveness of learning models. In the PBL context, this variation can include differences in the level of problem elaboration, the quality of teacher facilitation, and the suitability of the problem to the students' local context. Furthermore, Glass et al. (1981) and Cooper et al. (2019) emphasized that a good meta-analysis should not only report aggregate effect sizes but also explore sources of heterogeneity that can explain the variation in findings across studies.

The findings of this meta-analysis have important theoretical implications for the development of social constructivist learning theory. The results strengthen the basic assumption of Vygotsky & Cole (1978) about the zone of proximal development (ZPD), which states that effective learning occurs when students are given structured challenges with appropriate support from teachers or peers. In PBL, explicitly structured problem-solving appears more effective in facilitating the development of students' scientific literacy through social interaction in small groups focused on specific problems. This aligns with Piaget (1970) view of knowledge construction through assimilation and accommodation, where cognitive conflict arising when facing problems in PBL encourages the restructuring of students' schemata. Additionally, Ausubel et al. (1978) 's meaningful learning theory is also relevant in explaining the superiority of PBL because this model systematically activates students' prior knowledge before introducing new concepts through given problems. Bruner (1961), through discovery learning theory, also emphasizes the importance of active exploration processes in building science understanding, and PBL provides a systematic framework for that discovery process.

Practically, the results of this research provide recommendations for high school science teachers to prioritize the application of PBL in efforts to improve students' scientific literacy, especially if learning time availability is limited. Although PjBL still positively impacts the large category, its lower effectiveness than PBL indicates that PjBL implementation needs to be designed more carefully to ensure that student involvement in project making does not reduce the depth of their conceptual understanding. Teachers need to place a stronger emphasis on the science aspects of the project being worked on and ensure that the scientific investigation process remains the core of PjBL activities. This implication aligns with the findings of Sawyer (2005) and Larmer et al. (2015) on the importance of gold standards in PjBL implementation to achieve optimal learning outcomes, including scientific literacy aspects. Furthermore, Tseng et al. (2013) and Han et al. (2015) also emphasized that the effectiveness of PjBL depends on the quality of project design, resource availability, and the duration and consistency of implementation.

CONCLUSION

Based on the results of a meta-analysis of 14 primary studies that met the inclusion criteria, it can be concluded that the Problem-Based Learning (PBL) model is more effective than Project-Based Learning (PjBL) in improving high school students' science literacy skills in science classes. The combined average effect size for PBL was 1.76 (very large category), while PjBL reached only 0.77 (large category), with a difference of 0.99 points, clearly indicating the quantitative superiority of PBL. Although both models have a positive effect, the high level of heterogeneity in the PBL studies (I^2 = 91.45%) highlights the need for further exploration of moderating factors such as content type, intervention duration, and sample characteristics. Therefore, science teachers are advised to prioritize the implementation of PBL to optimize students' science literacy, while the implementation of PjBL needs to be redesigned with a stronger emphasis on scientific inquiry to enhance its effectiveness and bring it closer to the outcomes achieved by PBL.

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