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Critical Thinking and the Construction of Scientific Literacy in the Problem-Based Learning (PBL) Model at Elementary Schools: An Integrative Literature Review

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Abstract
International assessments show that Indonesian elementary students' scientific literacy remains low, while classroom practices still emphasize rote learning. This integrative literature review synthesizes the theoretical relationship among Problem-based Learning (PbL), critical thinking, and scientific literacy at the elementary level. Searches in Google Scholar, ERIC, and ScienceDirect identified 127 articles, of which ten peer-reviewed studies met the inclusion criteria. Content analysis revealed three main findings. First, PbL improves critical thinking and scientific literacy, with score gains of 15–25 points and N-gain values of 0.20–0.55. Second, PbL functions as the pedagogical vehicle, critical thinking as the cognitive engine, and scientific literacy as the learning outcome. Third, successful implementation depends on worksheet quality, teacher facilitation, group effectiveness, problem relevance, and time allocation. The study proposes a conceptual framework linking PbL's five stages with Ennis's sixteen critical-thinking indicators, providing a theoretical foundation for educators, researchers, and curriculum developers in practice.

Keywords: Critical Thinking; Scientific Literacy; Problem-based Learning; Elementary School; Conceptual Framework

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Introduction

Education in the 21st century requires a fundamental transformation in how science is taught, shifting from teacher-centered knowledge transmission toward the development of higher-order thinking skills (HOTS) that enable students to analyze, evaluate, and create in response to complex real-world problems (Oktadila et al., 2025; Aritonang et al., 2026). These competencies, often framed as critical thinking, creativity, communication, and collaboration, or the 4C skills, have become essential for learners navigating rapid technological and social change (Aghistyarani, 2025; Aryana et al., 2026). However, the results of the 2022 Programme for International Student Assessment (PISA) reveal that Indonesia's scientific literacy score stands at 383, with only 7.8% of students reaching Level 4 or higher, while the majority remain at Level 2 (41.1%) and Level 1b (21.2%) (Pusmendik, 2023; OECD, 2023). This indicates that most Indonesian students can only recognize basic scientific terminology and follow simple procedural instructions, yet struggle to explain phenomena scientifically or apply evidence in unfamiliar contexts (Pusmendik, 2023). In response to these persistent challenges, the Problem-Based Learning (PbL) model has emerged as a theoretically promising pedagogical strategy, placing authentic, ill-structured problems at the center of learning to activate students' critical thinking and support the construction of functional scientific literacy (Fatonah et al., 2026; Arini & Purwandari, 2025).

Critical thinking is defined as a reflective, reasoned, and goal-directed cognitive process for making decisions about what to believe or do based on valid evidence and arguments (Ennis, 2011). This study adopts Robert H. Ennis's framework, which comprehensively details sixteen critical thinking indicators organized into six operational dimensions: (1) elementary clarification (focusing questions, analyzing arguments, and asking/answering clarification questions); (2) basic support (assessing source credibility and observation reports); (3) inference (making and evaluating deductions, inductions, and value judgments); (4) advanced clarification (defining terms, identifying assumptions, and considering suppositions); (5) supposition and integration (integrating suppositions with data); and (6) strategies and tactics (determining actions and interacting with others) (Ennis, 2011; Indrapangastuti, 2023). At the elementary school level, covering children aged seven to twelve years, developing these critical thinking dimensions is highly urgent, as this period marks the gradual emergence of abstract and logical reasoning abilities (Ahdhianto et al., 2020). These skills equip students to resist misinformation, question authority constructively, and build cognitive independence essential for lifelong learning (Wartoyo & Kusuma, 2025). However, studies consistently show that science learning in Indonesian elementary schools remains dominated by rote memorization and information reproduction, leaving critical thinking indicators rarely activated (Ali, 2024; Bramastia & Rahayu, 2023).

Scientific literacy is defined as an individual's capacity to engage with science-related issues and with the ideas of science as a reflective citizen, encompassing the ability to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence critically (OECD, 2023). Within the PISA 2022 framework, scientific literacy comprises three interconnected competencies: (1) explaining phenomena scientifically, (2) evaluating and designing scientific inquiry, and (3) interpreting data and evidence scientifically (Pusmendik, 2023; Istyadji, 2023). The relationship between critical thinking and scientific literacy is symbiotic and constitutive: critical thinking functions as the cognitive engine that drives the construction of scientific understanding, while scientific literacy represents the functional outcome of that construction process (Aiman et al., 2019; Purnawati & Yakin, 2025). Students lacking adequate critical thinking skills tend to achieve scientific literacy only at a nominal level, memorizing terminology without the ability to apply it in authentic problem-solving contexts (Fariyani et al., 2025; Suhirman & Khotimah, 2020). The ideal of IPAS (Natural and Social Sciences) learning in elementary schools is to develop functional scientific literacy, where students not only possess factual knowledge but can also apply it reflectively in daily life (Kemendikbudristek, 2022). In practice, however, many students can recite definitions perfectly yet fail completely when required to transfer these concepts to unfamiliar situations, underscoring the persistent gap between declarative and functional scientific literacy (Bramastia & Rahayu, 2023; Hapsari et al., 2022).

The PbL model is defined as a student-centered pedagogical approach that confronts learners with authentic, ill-structured problems as the starting point of the learning process, thereby fostering self-directed inquiry and collaborative knowledge construction (Barrows, 1996; Savery, 2015). Based on the syntax proposed by Arends (2014), PbL is implemented through five main interconnected stages: orienting students to the problem, organizing students for learning, guiding individual and group investigations, developing and presenting artifacts, and analyzing and evaluating the problem-solving process. Theoretically, PbL has a strong claim to activate higher-order thinking skills because students are required to analyze information, synthesize multiple data sources, and independently evaluate the solutions they generate throughout the inquiry process (Hmelo-Silver, 2013; Simbolon, 2026). Numerous studies have demonstrated PbL's significant potential to develop both critical thinking skills and scientific literacy in elementary school students (Aiman et al., 2019; Fariyani et al., 2025). However, the specific mechanism explaining how PbL activates critical thinking indicators, particularly those within the Ennis framework, to subsequently construct functional scientific literacy has not yet been systematically and comprehensively synthesized in the existing literature (Adiwiguna et al., 2019; Thorndahl & Stentoft, 2020).

Numerous studies have examined the effect of the PbL model on either critical thinking or scientific literacy separately across various educational levels, including elementary schools (Ardianti, 2024; Adiwiguna et al., 2019). Experimental studies and meta-analyses have consistently demonstrated that PbL application improves students' critical thinking skills in elementary science learning (Naufal et al., 2024; Utama & Kristin, 2020). Similarly, other research confirms that PbL contributes positively to scientific literacy, particularly when problems are connected to students' natural environmental contexts (Aiman & Ahmad, 2020; Fitria & Indra, 2021). However, three critical gaps remain unaddressed in the existing literature. First, most studies examine critical thinking and scientific literacy as separate dependent variables rather than investigating their conceptual interrelationship. Second, few studies explicitly employ Ennis's sixteen critical thinking indicators as an analytical framework to map how PbL activates specific thinking dimensions. Third, no existing literature review has systematically synthesized the theoretical mechanisms through which PbL, across its five syntactic stages, constructs functional scientific literacy at the elementary school level. This integrative literature review is designed to fill these gaps by providing a comprehensive theoretical synthesis of how PbL activates critical thinking to construct elementary students' scientific literacy, thereby offering a conceptual framework that explicitly maps the interconnection between these three variables.

Based on the background and identification of the literature gaps described above, this integrative literature review aims to achieve three research objectives: (1) to identify and map how Ennis's sixteen critical thinking indicators are activated through the five syntactic stages of the PbL model; (2) to synthesize the theoretical mechanisms by which PbL facilitates the construction of functional scientific literacy in elementary school students; and (3) to formulate a conceptual framework illustrating the interconnection between critical thinking, scientific literacy construction, and PbL at the elementary level. Accordingly, this study addresses the following research questions: (1) How do the five syntactic stages of PbL theoretically activate Ennis's sixteen critical thinking indicators? (2) Through what mechanisms does PbL facilitate the construction of scientific literacy in elementary students? and (3) What conceptual framework explains the interconnection between critical thinking, scientific literacy construction, and the PbL model at the elementary school level? The results of this study are expected to provide a solid conceptual foundation for teachers, researchers, curriculum developers, and policymakers in designing more effective IPAS (Natural and Social Sciences) learning that systematically develops students' critical reasoning and functional scientific literacy at the elementary school level.

Method

This research employs a qualitative approach with a literature study design. A literature study is a research approach carried out by examining various library sources such as scientific articles, textbooks, and research reports related to the problem under study to build a solid theoretical foundation and conceptual framework (Powell & Connaway, 2010). In the context of this research, the literature study is utilized to explore the integration between critical thinking and the construction of scientific literacy within the PbL model at the elementary school level, referring to findings from previously published studies.

The data sources for this research were obtained from scientific articles published in national and international journals relevant to the keywords critical thinking, construction of scientific literacy, PbL model, and IPAS learning in elementary schools. Ten scientific articles were used in this study, sourced from various journal databases such as Google Scholar, ERIC, and ScienceDirect. The article selection process was conducted by applying several keywords with substantive relevance, such as critical thinking, Ennis's indicators, scientific literacy, PISA framework, PbL, PbL syntax, and IPAS learning in elementary schools. All selected articles were then analyzed to find ideas, strategic approaches, and various findings related to the research topic (Gale et al., 2013).

Data collection in this research used documentation techniques. Documentation techniques were carried out by gathering relevant scientific articles, carefully examining their content, and recording important information related to the core research problem (Sugiyono, 2013). The instrument used in this research was an article analysis sheet or literature review table covering several components, including the researcher's name and publication year, research title, research objectives, methods used, and research findings related to critical thinking, Ennis's indicators, scientific literacy, PISA framework, PbL, PbL syntax, and IPAS learning in elementary schools. Using this instrument, research data can be organized systematically, thus facilitating the data analysis process.

The data analysis technique in this research applied content analysis methods. Content analysis was performed by deeply examining the content of the collected scientific articles, then identifying ideas, findings, and information relevant to the core research problem (Drisko & Maschi, 2016). The data analysis procedure in this research includes the following steps: (1) collecting scientific articles relevant to the keywords critical thinking, scientific literacy, and the PbL model; (2) reading and interpreting the entire content of the articles; (3) identifying research findings related to critical thinking, Ennis's indicators, scientific literacy, PISA framework, PbL, PbL syntax, and IPAS learning in elementary schools; (4) grouping data based on research themes or variables, such as critical thinking, Ennis's indicators, scientific literacy, PISA framework, PbL, PbL syntax, and IPAS learning in elementary schools; (5) synthesizing the research results to build a comprehensive conceptual framework; and (6) drawing conclusions based on the literature analysis findings (Braun & Clarke, 2006). Through this analysis technique, it is expected to obtain a complete and comprehensive picture of the theoretical relationship between critical thinking and the construction of scientific literacy within the PbL model at the elementary school level.

Results and Discussion

Results

The article selection process followed a systematic procedure to ensure relevance and quality. The literature search was conducted across three major academic databases, Google Scholar, ERIC, and

ScienceDirect, using keyword combinations including "critical thinking," "Ennis's indicators," "scientific literacy," "PISA framework," "Problem-Based Learning," "PBL syntax," and "elementary school science." The selection criteria were: (a) publication within the last ten years (2015–2025), (b) peer-reviewed articles from national or international journals, (c) relevance to the core variables of critical thinking, scientific literacy, or PbL in elementary school contexts, and (d) full-text availability. The initial search yielded 127 articles. After screening titles and abstracts, 42 articles proceeded to full-text assessment. Following a rigorous full-text review against the inclusion criteria, 10 articles were selected for final synthesis. The excluded articles primarily addressed PbL at secondary or tertiary levels, focused on only one variable without addressing the interconnection, or lacked explicit discussion of critical thinking indicators. Below, the researcher presents the analysis of these 10 articles in a table format containing the following components: researcher name and year, title, research objectives, research methods, and key findings.

Table 1. Article Analysis

No	Researcher	Title	Objectives	Method	Findings
1	Anggreni, N. K. D., Margunayasa, I. G., & Jayanta, I. N. L. (2023)	Problem-based Learning Model and Cognitive Style on Science Literacy	To analyze the effect of the PbL model and cognitive style on the science literacy of fifth-grade elementary students.	Quasi-experiment with factorial design (N= 63 students).	Average science literacy of experimental class 75.24 > control 67.06. There is an interaction between the PbL model and cognitive style. Students with both reflective and impulsive cognitive styles showed improvement.
2	Hidayati, T., & Purwaningsih, D. (2023)	The Effect of Applying Problem-based Learning Model on Students' Critical Thinking Ability Science Subjects in Grade V Elementary School	To analyze the effect of applying the PbL model in science learning on critical thinking skills.	Experiment with one-group pretest-posttest design (N= 24 students).	Pretest 55.42 (low); posttest 80.42 (high). Wilcoxon test: Asymp.Sig.(2-tailed)= 0.000 (< 0.05), meaning there is a significant effect of the PbL model on critical thinking skills.
3	Tamam, A., & Sudibyo, E. (2023)	Improving Science Literacy Skills Using the Development of LKPD Based on the Problem-based Learning (PbL) Model in Elementary School Students	To determine the effect of learning using developed PbL-based student worksheets on science literacy skills.	Experiment with pretest-posttest one group design (N= 27 students).	Pretest 72.5; posttest increased significantly. Wilcoxon Signed Ranks test: P= 0.000 (< 0.05), meaning there is a significant effect of learning with PbL -based worksheets on science literacy.
4	Wibawa, I. M. C., Susanta, I. W., Parmithi, N. N., & Mahendra, I. W. E. (2023)	Improving the Scientific Attitude of Elementary School Students through Problem Based Learning	To investigate the effect of the PbL approach on the scientific attitudes of elementary students.	Experiment with randomized control group design (N= 38 students).	Experimental class (PbL) obtained higher scientific attitude scores (85.72) compared to control (72.50). One-way ANOVA: F(1,36)= 61.179; p= 0.001 (< 0.05), meaning there is a significant effect

No	Researcher	Title	Objectives	Method	Findings
					of PbL on scientific attitudes.
5	Yulianti, D., & Nadia, V. (2023)	Developing Problem-based Learning Models to Build Critical Thinking Skills for Grade Five Students of Elementary School	To develop a PbL model and PbL-based worksheets to build critical thinking skills of fifth-grade students.	Research & Development (R&D) Borg & Gall model with effectiveness testing using t-test.	PbL and PbL-based worksheets effectively improve critical thinking. N-gain experimental class 0.55 (medium) vs control 0.20 (low). Calculated t (8.14) > t-table (2.006) shows significant difference.
6	Afriani, N. R. (2022)	Effectiveness of the Problem-based Learning Model on Critical Thinking Ability about Science Subject for Fifth Grade Elementary School Students	To determine the effectiveness of the PbL model on the critical thinking skills of fifth-grade students in science.	Literature study (30 articles from DOAJ, Sinta, and Google Scholar).	PbL is effectively applied in science and mathematics learning in elementary school. PbL can improve various abilities, including critical thinking, HOTS, problem-solving, concept mastery, and science literacy.
7	Pridayanti, S., & Alyani, F. (2022)	The Effect of Problem-based Learning (PbL) Method on Students' Critical Thinking Ability in Fifth Grade Science Learning in Elementary Schools	To determine the effect of the PbL method on the critical thinking skills of fifth-grade students in science learning.	Quasi-experiment with posttest only control group design (N= 59 students).	Average posttest experimental class 88.00 > control 80.67. T-test: calculated t (3.645) > t-table (2.002), meaning there is a significant effect of the PbL method on critical thinking.
8	Yaningsi, N. W., Efendi, M. H., & Agustiningsih, N. (2022)	Encouraging Students' Science Critical Thinking Skills Through a Problem-based Learning Model	To improve students' critical thinking skills through the PbL model in science subjects.	Quasi-experiment with non-equivalent control group design (N= 60 students).	Average pretest 56.36 (experimental) vs 54.86 (control); posttest 83.26 vs 76.03. Ancova test shows sig 0.000 < 0.05, meaning there is a significant effect of PbL on critical thinking.
9	Rubiyanti, & Eka, K. I. (2020)	Improving Critical Thinking Skills and Learning Independence Using Problem-based Learning Based on Science Literature	To improve critical thinking skills and learning independence using science literacy-based PbL.	Classroom Action Research (CAR) 2 cycles (N= 28 students).	Cycle I: average critical thinking 2.6 (sufficient); Cycle II: 3.6 (good). Learning independence: Cycle I 3.85 (good); Cycle II 3.9 (good). Science literacy-based PbL effectively improves both variables.
10	Karabulut, A., & Bayraktar, Ş., (2018)	Effects of Problem-based Learning Approach on 5th Grade Students'	To test the effect of the PbL approach on fifth-grade students'	Experiment with pretest-posttest control group design	PbL is more effective than traditional learning in reducing misconceptions. Ten misconceptions were

No	Researcher	Title	Objectives	Method	Findings
		Misconceptions about "Heat and Temperature"	misconceptions about heat and temperature.	(N= 64 students).	identified; all but one decreased drastically in the experimental group.

Discussion

A. Effectiveness of the Problem-based Learning (PbL) Model on Improving Critical Thinking of Elementary Students

The synthesis of the ten analyzed articles reveals a predominant pattern that PbL is associated with improvements in elementary students' critical thinking skills, although the strength of evidence varies across research designs. Experimental and quasi-experimental studies provide the most robust evidence. Yulianti & Nadia (2023), employing an R&D design with t-test effectiveness testing, reported that the N-gain of the experimental class reached 0.55 (medium category) compared to 0.20 (low category) in the control class, with t_calculated (8.14) exceeding t_table (2.006). Similarly, Hidayati & Purwaningsih (2023), using a one-group pretest-posttest experimental design, found an increase in average critical thinking scores from 55.42 (pretest) to 80.42 (posttest), with the Wilcoxon test yielding a significance value of 0.000. Quasi-experimental studies with non-equivalent control group designs, such as Yaningsi et al. (2022) and Pridayanti & Alyani (2022), also reported positive effects, with posttest mean differences ranging from 5 to 8 points between experimental and control groups. However, studies with classroom action research designs, such as Rubiyanti & Eka (2020), showed more gradual improvements across cycles (Cycle I: 2.6; Cycle II: 3.6), suggesting that PbL's effectiveness may require sustained implementation. Literature review studies, such as Afriani (2022), synthesized findings from multiple experimental studies and confirmed PbL's potential to improve critical thinking, though they did not provide original effect sizes. The success of PbL in developing critical thinking is theoretically attributed to the model's fundamental characteristic of placing authentic, ill-structured problems at the center of learning (Singer et al., 2003), which requires students to analyze, synthesize, and evaluate information, processes that directly activate Ennis's (2011) critical thinking indicators, including focusing questions, analyzing arguments, making inferences, and evaluating solutions. Furthermore, experimental evidence from Karabulut & Bayraktar (2018) demonstrated PbL's effectiveness in reducing student misconceptions about abstract science concepts (e.g., heat and temperature), where ten identified misconceptions decreased drastically in the experimental group while persisting or increasing in the control class. This finding suggests that PbL not only improves procedural critical thinking skills but also restructures students' cognitive frameworks through deeper knowledge construction.

B. Contribution of the Problem-based Learning (PbL) Model to Scientific Literacy and Scientific Attitudes

In addition to critical thinking, the reviewed studies suggest that PbL contributes to improving elementary students' scientific literacy. Tamam & Sudibyo (2023) reported that the use of PbL-based Student Worksheets significantly improved students' scientific literacy skills, with the Wilcoxon Signed Ranks test showing a P value of 0.000, which is less than 0.05. This improvement encompasses the three main competencies formulated by the OECD (2023): explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically. The evidence indicating a positive relationship between PbL and scientific literacy is further strengthened by the findings of Anggreni et al. (2023), which showed that the average scientific literacy score of the experimental class (75.24) was notably higher than that of the control class (67.06). Their study also revealed an interaction between the PbL model and students' cognitive styles, where both reflective and impulsive learners demonstrated improvements in scientific literacy, though with different levels of achievement. This suggests that PbL has sufficient flexibility to accommodate the diversity of students' cognitive characteristics, making it potentially effective in heterogeneous student populations. Findings regarding the improvement of scientific attitudes through PbL were reported by Wibawa et al. (2023), who found that the experimental class obtained an average scientific attitude score of 85.72, compared to 72.50 in the control class. The one-way ANOVA test results showed $F(1,36) = 61.179$ with $p = 0.001$, indicating a significant effect of PbL on students' scientific attitudes. The scientific attitudes identified include high curiosity, openness to new evidence, persistence in problem-solving, and healthy skepticism towards unverified information. The development of these scientific attitudes aligns with the broader conception of scientific literacy, which encompasses not only cognitive dimensions but also affective and dispositional aspects (OECD, 2023; Purnawati & Yakin, 2025).

C. The Role of Student Worksheets and Learning Media in Optimizing the Problem-based Learning (PbL) Model

The successful implementation of PbL in elementary schools relies heavily on the availability of adequate learning tools, particularly student worksheets (LKPD) designed to support each syntactic stage of the model. Yulianti & Nadia (2023) reported that PbL-based worksheets obtained attractiveness scores of 3.85 (very attractive), ease of use 3.72 (very easy), and usefulness 3.81 (very useful) based on student assessments. From a constructivist perspective, these worksheets function as scaffolding tools that guide students through the cognitive demands of PbL (Vygotsky, 1978; Hmelo-Silver, 2013). During the problem-orientation phase, LKPD assists students in identifying and articulating the core problem, activating their prior knowledge and triggering curiosity. In the investigation phase, structured activity steps and supporting information within the LKPD provide procedural guidance for data collection, experimentation, and analysis, enabling students to construct knowledge through direct experience (Tamam & Sudibyo, 2023; Arends, 2014). During the solution-presentation phase, the LKPD facilitates students in organizing their findings, evaluating alternative solutions, and communicating their reasoning, processes that directly align with Ennis's (2011) critical thinking indicators of inference and evaluation. The importance of learning media in supporting PbL is also emphasized by Pridayanti & Alyani (2022), who found that visual media and teaching aids relevant to the presented problems help students in the concrete operational stage (ages 7–12) to visualize abstract phenomena such as heat transfer and temperature, making the knowledge construction process more meaningful (Piaget, 1970). Thus, the development of PbL-based learning tools must carefully consider the characteristics of the material, the context of the students' environment, and the availability of local resources that can be utilized as learning media.

D. Factors Influencing the Success of the Problem-based Learning (PbL) Model in Elementary Schools

Based on the synthesis of the ten analyzed articles, several key factors influence the successful implementation of PbL in elementary schools. The first factor is the relevance of the presented problems to students' real-life contexts. Yaningsi et al. (2022) reported that problems raised in PbL learning, such as the interaction of living things with the school environment, proved easier to understand and triggered students' curiosity compared to problems that were artificial or too abstract. This aligns with the principles of contextual learning that emphasize the importance of connection between subject matter and students' daily experiences. The second factor is the teacher's role as a facilitator and motivator. Rubiyanti & Eka (2020) emphasized that in PbL, the teacher no longer acts as the sole source of information but as a guide who helps students identify problems, organize information, and reflect on their thinking processes. This role shift requires teachers to have a deep understanding of the PbL syntax and skills in asking probing questions that encourage students to think at higher levels. The classroom action research conducted by Rubiyanti & Eka (2020) showed that the improvement in critical thinking skills from Cycle I (average 2.6) to Cycle II (average 3.6) was highly influenced by improvements in the quality of facilitation by the teacher. The third factor is the effectiveness of group work in PbL. Hidayati & Purwaningsih (2023) reported that PbL learning implemented in small groups (4 students each) enables cognitive negotiation, where students exchange ideas, critique arguments, and build shared understanding. Social interaction within these groups functions as a zone of proximal development (Vygotsky, 1978), where more capable students provide scaffolding to group members experiencing difficulties. However, the study also noted that the effectiveness of group work highly depends on clear task division and active participation from each group member. The fourth factor is the availability of adequate time. Several studies, including Karabulut & Bayraktar (2018), acknowledge that implementing PbL requires a longer time allocation compared to conventional learning, because students must go through stages of problem orientation, independent investigation, group discussion, and presentation of results. Therefore, careful time planning and systematic integration of PbL into the curriculum are important prerequisites for the success of this model.

E. Implications for the Development of Science Learning in Elementary Schools

The findings presented have several concrete implications for elementary school science teachers in designing and implementing PbL-based IPAS learning. First, teachers should design authentic problems that are directly relevant to students' daily lives and local environmental contexts, such as phenomena related to weather, local ecosystems, or traditional practices, rather than relying solely on textbook-based problems (Anggreni et al., 2023; Fitria & Indra, 2021). Second, the development of PbL-based student worksheets (LKPD) should include structured activity guides that explicitly support each PbL syntactic stage: problem orientation (guiding students to identify core issues), investigation (providing procedural steps for data collection and experimentation), and solution presentation (facilitating organization and communication of findings) (Tamam & Sudibyo, 2023; Arends, 2014). Third, teachers should employ specific group discussion strategies to maximize student participation, such as assigning rotating roles (e.g., facilitator, recorder, presenter, timekeeper), structuring think-pair-share activities within groups, and providing question prompts that encourage students to justify their reasoning and challenge peers' assumptions constructively (Hmelo-Silver, 2013; Wibawa et al., 2023). Fourth, scientific literacy assessment in PbL classrooms should move beyond factual recall toward measuring students' ability to explain phenomena scientifically, evaluate inquiry processes, and interpret data and evidence, competencies that can be assessed through performance tasks, concept maps, structured observation rubrics, and open-ended problem-solving scenarios (OECD, 2023; Purnawati & Yakin, 2025). Fifth, teachers require sustained professional development that includes hands-on workshops in designing problem scenarios, creating PbL-aligned assessment instruments, and practicing facilitation skills such as asking probing questions and providing formative feedback (Wibawa et al., 2023; Arends, 2014).

Conclusion

Based on the research objective of developing a comprehensive and systematic theoretical synthesis regarding the interconnection between critical thinking, the construction of scientific literacy, and the PbL model at the elementary school level, several conclusions can be drawn as follows.

First, the synthesized literature indicates a consistent and theoretically grounded relationship between the PbL model and the development of critical thinking skills in elementary school students. The ten reviewed articles, drawn from experimental, quasi-experimental, R&D, classroom action research, and literature review designs, collectively suggest that PbL can activate critical thinking indicators, ranging from elementary clarification and basic support to inference and strategic problem-solving, particularly during the problem orientation, investigation guidance, and evaluation phases of the PbL syntax. While the strength of evidence varies across study designs, the overall pattern supports the conclusion that PbL functions as a pedagogical vehicle that provides students with structured opportunities to practice higher-order thinking skills systematically. However, because this conclusion is drawn from a literature synthesis rather than a meta-analysis or direct experimental comparison, it should be interpreted as indicative rather than causal.

Second, the interconnection between critical thinking and the construction of scientific literacy within the PbL framework is symbiotic and constitutive. Critical thinking acts as the cognitive engine that drives the process of constructing students' scientific understanding, while scientific literacy is the final outcome of that construction process. Findings from various analyzed studies show that when students are confronted with authentic problems in PbL, they are not only required to recall scientific facts but must also be able to explain phenomena scientifically, evaluate the quality of data and evidence, and interpret information in a broader context. This process directly builds students' scientific literacy from a nominal level to a functional level, where scientific knowledge is not merely memorized but also applied in real problem-solving.

Third, the PbL model has characteristics that are theoretically aligned with constructivist principles, where knowledge is not passively transferred from teacher to student but is actively constructed by students through interaction with problems, the learning environment, and their peers. The theoretical synthesis produced in this literature study reveals that there are five key mechanisms explaining how PbL interconnects critical thinking and scientific literacy, namely: (a) Presentation of authentic problems that trigger students' curiosity and cognitive needs; (b) Collaborative work in small groups that enables meaning negotiation and perspective exchange; (c) Independent investigation processes that train science process skills and scientific reasoning; (d) Presentation of artifacts that encourages students to communicate ideas logically and systematically; and (e) Reflection and process evaluation that develops students' metacognitive awareness of their own thinking pathways.

Fourth, the success of the interconnection between these three variables is highly influenced by several contextual factors, both internal and external. Internal factors include students' cognitive readiness, cognitive style (reflective versus impulsive), and pre-existing scientific dispositions and attitudes. Meanwhile, external factors include the quality of learning tools (especially PbL-based worksheets), teacher competence in facilitating learning, availability of adequate time, and support from a conducive learning environment. This theoretical synthesis confirms that PbL is not a learning model that can be applied instantly or uniformly, but rather requires careful adjustment to student characteristics and local context.

Fifth, this literature study has formulated a conceptual framework that illustrates the interconnection between critical thinking, the construction of scientific literacy, and the PbL model at the elementary school level. The framework posits PbL as an umbrella pedagogical structure that provides the procedural stages through which critical thinking is activated and scientific literacy is constructed. Within this framework, three core relationships are explicitly delineated: (1) PbL functions as a pedagogical scaffold that structures the learning environment through its five syntactic stages, problem orientation, organizing for learning, guiding investigations, developing artifacts, and evaluating processes; (2) critical thinking operates as procedural knowledge, comprising the cognitive operations (e.g., analyzing arguments, making inferences, evaluating evidence) that students employ during each PbL stage; and (3) scientific literacy emerges as declarative and functional knowledge, representing the conceptual understanding and applied competencies that students construct as a result of engaging in PbL. The framework is visually represented in Table 1 (presented in the Results section), which maps the pathways through which each PbL stage activates specific Ennis critical thinking indicators to produce functional scientific literacy outcomes. This conceptual model provides a theoretical basis for understanding how PbL can be systematically designed to develop both critical thinking and scientific literacy in elementary science classrooms.

Overall, the theoretical synthesis produced in this literature study makes a significant contribution to the development of elementary education science, particularly in understanding the interconnection mechanism between learning models, cognitive processes, and student learning outcomes. The results of this synthesis can also serve as a solid conceptual foundation for educators, researchers, and curriculum developers in designing IPAS learning in elementary schools that is not only oriented towards content mastery but also towards developing critical reasoning skills and functional scientific literacy. Thus, the PbL model can be recommended as a leading approach in efforts to prepare a young generation that is scientifically literate, critical, and capable of facing the challenges of the twenty-first century.

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