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Enhancing Conceptual Understanding in Elementary Science Learning through the Problem-Based Learning Model: A Literature Review

Kamaludin Irsyad[1], Zumrotul Fauziah[2], Mukti Ali[3]
Institut Agama Islam Negeri Salatiga [1,2,3]
E-mail: kirsyad30@gmail.com

Abstract
Problem-Based Learning (PBL) has been widely recognized as an effective pedagogical model for improving students' understanding of science by encouraging active engagement, critical thinking, and problem-solving. This study aimed to analyze conceptually how the application of PBL can enhance students' comprehension in natural science learning at the elementary school level. A library research design was employed, drawing upon books, journal articles, and relevant prior studies, which were systematically reviewed and synthesized to examine theoretical foundations, practical implementations, and empirical findings of PBL in science education. The analysis revealed that PBL facilitates higher-order thinking skills by providing authentic problem contexts that require inquiry, collaboration, and reflective learning, thereby improving students' conceptual mastery and their ability to connect scientific principles with real-life experiences. Furthermore, PBL was shown to strengthen creativity, motivation, communication, and collaboration among learners, making it an appropriate model to prepare students with competencies aligned to 21st-century education. The novelty of this study lies in its contextualization of PBL within Indonesian elementary education, highlighting both its theoretical potential and practical relevance for improving science literacy. The findings imply that educators, curriculum developers, and policymakers should consider integrating PBL as a strategic instructional model to enhance the quality of science teaching and learning, while future studies are encouraged to validate these insights through classroom-based empirical research.

Keywords: Conceptual Understanding; Critical Thinking; Elementary School; Problem-Based Learning; Science Education.

INTRODUCTION

Science education at the elementary level plays a crucial role in shaping students' understanding of natural phenomena and fostering their ability to think critically and systematically. Natural science, commonly referred to as *Ilmu Pengetahuan Alam* (IPA) in Indonesia, is not only about acquiring factual knowledge but also about cultivating inquiry, discovery, and problem-solving skills that enable learners to make sense of their environment (Putri et al., 2021). At its core, science education is designed to help students develop attitudes, skills, and knowledge necessary for scientific literacy, which prepares them to engage with societal and environmental challenges in an informed manner (Adauyah & Aznam, 2024; Baltikian et al., 2024; Hogan & O'Flaherty, 2021). However, in practice, many elementary students tend to perceive science as a body of knowledge to be memorized rather than a dynamic process of inquiry and reasoning, resulting in shallow conceptual understanding and limited transfer of knowledge to real-life contexts (Cai et al., 2022; Kotsis, 2024; Valente et al., 2024).

Traditional teaching approaches in science classrooms often emphasize rote learning and the transmission of facts, which limits opportunities for students to engage in authentic scientific practices. Such approaches prioritize short-term recall over critical thinking and problem-solving, thereby reducing students' ability to apply concepts in new situations (French et al., 2024; Kotsis, 2024; Martin-Alguacil et al., 2024). This issue has been consistently highlighted in research showing that students who primarily experience lecture-based or teacher-centered instruction struggle to integrate concepts and develop higher-order thinking skills (Darling-Hammond et al., 2020; Martin-Alguacil et al., 2024; Woods & Copur-Gencturk, 2024). Consequently, the call for innovative learning models in science education has grown stronger, with scholars advocating for approaches that are student-centered, inquiry-driven, and contextually relevant to learners' experiences (Ammar et al., 2024; Darling-Hammond et al., 2020; Kotsis, 2024).

PBL has emerged as one of the most promising pedagogical models to address these challenges. PBL is an instructional method that uses real-world problems as a starting point for learning, encouraging students to actively construct knowledge, collaborate with peers, and develop problem-solving skills (Akcay & Benek, 2024; Wijnia et al., 2024; Wu, 2024). In the PBL framework, students are guided to identify problems, generate hypotheses, collect and analyze information, and reflect on their learning processes, which mirrors the authentic practices of scientific inquiry (Drăghicescu et al., 2014; Nicholus et al., 2023; Rafiq et al., 2023). Several studies have confirmed that PBL not only improves conceptual understanding but also enhances critical thinking, creativity, and communication skills (Darwin et al., 2024; Jumhur et al., 2024; Nicholus et al., 2023). These competencies are particularly important in elementary education, as they provide a foundation for lifelong learning and adaptability in a rapidly changing world (Darling-Hammond et al., 2020; Van den Broeck et al., 2024; Zamiri & Esmaeili, 2024).

The integration of PBL into natural science learning at the elementary level is especially relevant given that science phenomena are often best understood through contextual, hands-on, and problem-oriented approaches. By situating learning within authentic problems, PBL makes abstract scientific concepts more concrete and meaningful, thereby bridging the gap between theory and practice (Akcay & Benek, 2024; Darling-Hammond et al., 2020; Widowati et al., 2021). For instance, when students investigate environmental issues such as waste management, water conservation, or energy use, they not only apply scientific concepts but also develop socio-scientific reasoning and civic responsibility (Ariza et al., 2021; Rahmania, 2024; Viehmann et al., 2024). Moreover, research in Indonesian contexts indicates that PBL can improve motivation, deepen understanding, and foster collaboration among students, making it a viable model for local classrooms (Jumhur et al., 2024; Sisrayanti et al., 2024; Yunianto et al., 2024).

Despite the growing evidence supporting PBL, there remain notable gaps in the literature. Much of the existing research has focused on secondary or higher education, with relatively limited attention to elementary-level science learning, particularly in Indonesia. Furthermore, while previous studies have documented the benefits of PBL in promoting critical thinking and conceptual understanding, fewer have systematically explored its role in addressing the persistent issue of students' shallow comprehension of natural science concepts at the elementary level (Akcay & Benek, 2024; Ayu et al., 2024; Uliyandari et al., 2021). Another gap lies in the limited availability of synthesized conceptual reviews that integrate both international findings and localized evidence to guide teachers in effectively implementing PBL in elementary classrooms.

Therefore, the purpose of this study is to provide a comprehensive conceptual analysis of the Problem-Based Learning model and its potential for enhancing students' understanding of natural science in elementary education. By synthesizing theoretical foundations, empirical research, and contextual applications, this study seeks to highlight the relevance of PBL in addressing the limitations of traditional science instruction, while also offering practical insights for educators and policymakers aiming to strengthen science education in Indonesia.

METHODS

This study employed a library research design, focusing on an in-depth review and critical analysis of literature related to the implementation of the PBL model in elementary science education. The research process began with the systematic identification and collection of relevant sources, including peer-reviewed journal articles, books, conference proceedings, and government documents published within the last two decades, with emphasis on materials from the past ten years to ensure the inclusion of current perspectives. The selection of literature followed predefined criteria, namely relevance to PBL in the context of science learning, contribution to conceptual understanding, and empirical evidence of PBL effectiveness in improving students' comprehension, critical thinking, and problem-solving skills. To maintain academic rigor, multiple electronic databases such as Google Scholar, ERIC, Scopus, and national journals were searched using keywords including "Problem-Based Learning," "science education," "conceptual understanding," and "elementary students." Duplicate entries were removed, and each document was screened based on title, abstract, and keywords before inclusion. The analysis employed content analysis techniques, where selected literature was categorized into thematic areas such as definitions and principles of PBL, its pedagogical implications, challenges of implementation, and reported impacts on learning outcomes. Comparative synthesis was then carried out to identify convergences and divergences in research findings across studies, followed by an interpretive evaluation of how these findings could inform improvements in the teaching and learning of natural sciences at the elementary level. To ensure credibility and minimize bias, triangulation was applied by cross-referencing multiple sources for each theme, and the findings were validated against established theoretical frameworks in science education. Ethical considerations were also observed in this study, particularly in acknowledging all sources accurately, avoiding plagiarism, and adhering to international standards of academic integrity. Through this methodological approach, the study sought to generate a comprehensive understanding of the role of PBL in enhancing conceptual mastery in science education and to provide evidence-based recommendations for future practice and research.

RESULTS AND DISCUSSION

Synthesis of Literature on PBL in Science Education

The analysis of the selected literature revealed that Problem-Based Learning (PBL) has consistently been reported as an effective pedagogical model for enhancing students' conceptual understanding, critical thinking, and problem-solving abilities in science education. Across various studies, PBL was described not merely as a teaching method but as a learner-centered approach that situates knowledge acquisition within authentic, real-world problems. Evidence indicated that students exposed to PBL developed stronger reasoning skills, greater motivation, and deeper engagement with science concepts compared to those taught through traditional lecture-based methods.

Identified Themes from Literature Review

From the content analysis, several thematic categories emerged. First, the literature emphasized the definition and principles of PBL, which integrate inquiry, collaboration, and self-directed learning. Second, the pedagogical benefits of PBL were widely reported, including improved conceptual mastery, scientific reasoning, and higher-order thinking. Third, studies highlighted challenges of PBL implementation, such as the need for teacher readiness, appropriate resources, and alignment with curriculum demands. Finally, empirical outcomes consistently demonstrated that PBL contributes to increased student motivation and creativity in science classrooms.

Comparative Synthesis with Existing Research

Table 1. Sintaks Problem Based Learning

Sintaks	Teacher's Behavior
Students' Orientation to the Problem	The teacher explains the learning objectives, clarifies the necessary logistics, and motivates students to engage in the selected problem-solving activity.
Organizing Students for Learning	The teacher assists students in defining and organizing learning tasks related to the problem.

Sintaks	Teacher's Behavior
Guiding Individual and Group Investigations	The teacher encourages students to gather relevant information, conduct experiments, and seek explanations and solutions to the problem.
Developing and Presenting Work Products	The teacher supports students in planning and preparing appropriate products such as reports, videos, or models, and helps them share tasks with their peers.
Analyzing and Evaluating the Problem-Solving Process	The teacher guides students in reflecting on or evaluating the investigation and the processes used.

The findings of this review are consistent with the conclusions of Jumhur (2024), who reported that PBL stimulates higher-order thinking and requires a supportive classroom environment for successful implementation. Similar results were documented by Afra (2009), who found that PBL encouraged students to engage in collaborative inquiry and problem-solving in primary-level social studies, outcomes that parallel the benefits observed in science education. Furthermore, Marthaliakirana (2022), demonstrated that PBL enhanced both reasoning and scientific literacy among junior high school students, reinforcing the claim that PBL supports the development of essential 21st-century skills. Internationally, studies by Sukackė (2022) and Nicholus (2024) also confirmed that PBL environments cultivate deeper conceptual understanding and student autonomy compared to conventional methods. More recently, Yu (2024) emphasized that PBL continues to be relevant for fostering critical and reflective thinking across educational contexts. These comparisons strengthen the validity of the present review by situating its findings within a broader evidence base.

The novelty of this research lies in its focus on synthesizing literature specifically addressing PBL within the context of elementary science education in Indonesia, an area that remains underexplored compared to studies conducted at secondary or tertiary levels. While much of the existing literature documents the general advantages of PBL, fewer studies have systematically mapped its relevance and challenges in primary-level science classrooms where students are in the formative stages of conceptual development. This review therefore contributes to filling that gap by consolidating both national and international findings and situating them within the local educational context. The implications of this study are significant for teachers, curriculum developers, and policymakers. For teachers, the findings suggest that adopting PBL can transform science learning from rote memorization into inquiry-driven exploration, thereby cultivating critical thinking and problem-solving from an early age. For curriculum developers, integrating PBL into instructional design could support the national agenda of promoting scientific literacy and 21st-century competencies. Policymakers, in turn, could leverage these insights to strengthen professional development programs that equip teachers with the skills and resources necessary to implement PBL effectively in diverse classroom contexts.

Despite its contributions, this study has several limitations. Being a library-based review, it relied on secondary data rather than primary empirical investigation, which may restrict the depth of contextual analysis. The literature sample was limited to published works accessible through selected databases, potentially omitting relevant gray literature or unpublished studies. Furthermore, the majority of included studies were descriptive rather than experimental, making it difficult to generalize the outcomes across all contexts. Future research should therefore employ empirical classroom-based investigations of PBL in elementary science education, with larger and more diverse samples, to validate and extend the findings of this review.

CONCLUSION

This study highlights that the application of the Problem-Based Learning (PBL) model in elementary science education is effective in fostering students' conceptual understanding, critical thinking, and problem-solving abilities, while simultaneously enhancing creativity, motivation, communication, and collaboration skills that are essential for 21st-century learning. By shifting the focus from rote memorization to inquiry-oriented and contextualized learning, PBL provides opportunities for students to actively construct knowledge through the investigation of real-life problems, thereby bridging the gap between scientific concepts and everyday experiences. The novelty of this research lies in its comprehensive conceptual analysis of PBL within the Indonesian elementary school context, offering empirical and theoretical insights into how the model can be adapted to strengthen science literacy and cultivate higher-order thinking. The findings imply that teachers, curriculum designers, and policymakers should consider PBL not only as an alternative but as a strategic pedagogical approach to improve the quality of science education. Nevertheless, as this study is based on literature review and conceptual synthesis, its conclusions remain limited by the scope of selected sources and the absence of classroom-based experimental validation. Future research should therefore integrate empirical classroom trials and cross-contextual analyses to further substantiate the effectiveness of PBL in advancing science learning outcomes across diverse educational settings.

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