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How Problem-Based Learning Enhances Critical Thinking? An Analysis of Contexts, Methods, and Findings from Previous Research

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Abstract

This review critically evaluates the effectiveness of Problem-Based Learning (PBL) in fostering critical thinking (CT) through a systematic analysis of experimental and quasi-experimental studies from the past decade. It synthesizes evidence across diverse contexts to identify factors influencing the success of PBL, emphasizing its contextual adaptability and methodological diversity. Notably, this review not only compiles existing evidence but also provides a nuanced analysis of the contextual and methodological elements affecting PBL's success in enhancing CT. The findings reveal that while PBL is generally effective, its superiority over traditional methods is not guaranteed, with some studies reporting comparable outcomes. High-achieving students particularly benefit from PBL, although its impact on problem-solving skills—a vital component of CT—is less pronounced. These insights underline the need for tailored PBL strategies to address its limitations and optimize its benefits. This review suggests integrating complementary methods such as technology and collaborative tools to enrich PBL. Future research should explore innovative adaptations that enhance all dimensions of CT across varied educational settings, thereby maximizing the pedagogical potential of PBL. This comprehensive evaluation provides critical insights for educators and policymakers aiming to advance CT development in contemporary education.

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INTRODUCTION

Critical thinking (CT) represents a crucial educational outcome that has gained increasing importance as we move toward the future, where skills such as logical problem-solving and analytical reasoning are essential in both academic and professional contexts. As predicted by Liu & Pásztor (2022), CT will be a cornerstone of educational achievement, playing a vital role in preparing students for complex problem-solving tasks and decision-making processes in various fields. The educational landscape, particularly within higher education, faces the ongoing challenge of effectively integrating CT into existing curricula. This challenge is exacerbated by the difficulties inherent in embedding CT instruction within well-established academic programs and in utilizing pedagogical strategies that foster the

development of this sophisticated cognitive skill (Dwyer et al., 2014; Prayogi et al., 2018). Problem-Based Learning (PBL), an instructional strategy that emphasizes active, student-centered learning through problem-solving, has emerged as a promising method for cultivating CT in higher education settings (Evendi et al., 2022). Despite its widespread application, the effectiveness of PBL in enhancing CT remains a subject of debate, necessitating a thorough review of existing literature to better understand its impact and the factors influencing its success (Suhirman & Ghazali, 2022).

The importance of CT in contemporary education cannot be overstated, as it is recognized as one of the critical competencies required for success in the 21st century (Ekayanti et al., 2022). CT encompasses a range of cognitive processes, including the ability to evaluate evidence, reason logically, and make well-founded decisions. However, despite its recognized value, defining CT with precision poses significant challenges due to its complex nature as a psychological construct. Various scholars have attempted to delineate the dimensions of CT, with definitions often converging on key characteristics such as reasoned, reflective thinking aimed at determining what to believe or do (Ennis, 2011). Although the complexity of CT makes it difficult to encapsulate in a single definition, there is broad agreement among educators and researchers that CT involves both cognitive skills and a disposition towards critical inquiry (Ennis, 2015; Facione, 2020).

Teaching CT effectively presents a persistent challenge for educators, particularly at the undergraduate level, where many instructors struggle with the conceptual ambiguity and pedagogical complexities associated with CT education (Bensley & Murtagh, 2012). Despite these difficulties, a consensus has emerged among researchers that CT can indeed be taught and learned (Altun & Yildirim, 2023). Successful CT instruction depends on the use of appropriate teaching strategies and curricular materials that promote active learning, encourage interaction among students and instructors, and provide opportunities for students to apply their cognitive skills in meaningful contexts. Active learning strategies, such as PBL, have been identified as particularly effective in fostering CT, as they engage students in collaborative problem-solving tasks that require the application of critical reasoning and analytical skills (Anggraeni et al., 2023; Sarkingobir & Bello, 2024). Despite the lack of a universally accepted approach to teaching CT, the evidence suggests that instructional interventions that prioritize active student engagement and interaction are likely to yield positive outcomes (Fitriani et al., 2022).

PBL, as a student-centered instructional approach, is designed to promote the development of CT through a structured process that involves problem analysis, goal setting, resource collection, idea synthesis, and reflection on problem-solving experiences (Lin et al., 2010). This approach aligns well with the objectives of CT education, as it encourages students to engage in analytic reasoning, problem-solving, and collaborative learning—skills that are central to CT. The theoretical foundation of PBL suggests that it is an effective method for enhancing CT (Suhirman & Prayogi, 2023), because it integrates key components of critical thinking, such as reasoning and reflective inquiry, into the learning process (Verawati et al., 2019). PBL tasks are typically ill-defined and open-ended, requiring students to navigate complex, real-world problems that do not have straightforward solutions (Aliyu et al., 2023). This type of learning environment fosters the development of higher-order thinking skills, as students must critically evaluate information, formulate hypotheses, and engage in iterative problem-solving processes.

Quoted from the study by Liu & Pásztor (2022), that the versatility of PBL as an instructional method is evident in its various forms, which can be categorized based on the context in which learning takes place and the nature of student interaction. For example,

scenario-PBL, involves the application of problem-solving in real-life situations, while case-PBL, uses stories or scenarios derived from real life to structure classroom discussions. Furthermore, PBL can be implemented either collaboratively, with students working together to solve problems, or individually, with each student working independently (Suebnukarn & Haddawy, 2006). This approach to PBL, characterized by collaborative learning and discussion, is well-suited to fostering the development of CT, as it allows students to share diverse perspectives, challenge each other's ideas, and refine their reasoning through dialogue. In addition to its various forms, PBL is distinguished by several key characteristics that contribute to its effectiveness as a pedagogical tool for promoting CT. According to Savery (2006), these characteristics include a focus on student-led learning, open inquiry of authentic cases, problems that are closely related to the subject matter, collaboration among students, reflection on the learning process, and guidance from instructors. These elements of PBL align closely with the goals of CT education, as they encourage students to take an active role in their learning, engage with complex, real-world problems, and reflect critically on their problem-solving strategies. The emphasis on collaboration and reflection is particularly important, as these aspects of PBL provide students with opportunities to articulate their reasoning, receive feedback from peers and instructors, and refine their thinking through iterative processes.

PBL has been found to be particularly effective in promoting higher-order thinking skills among students who may otherwise engage in passive learning habits. Nguyễn (2021) noted that when students are presented with well-designed problem-based tasks and receive adequate support from instructors, they are more likely to develop and apply higher-order thinking skills, such as analysis, synthesis, and evaluation. These skills are essential components of CT, as they enable students to approach problems from multiple perspectives, assess the validity of different solutions, and make informed decisions based on evidence. The active, student-centered nature of PBL also helps students stay focused on the learning process, as they are required to engage deeply with the material and take ownership of their learning outcomes. Furthermore, the collaborative aspect of PBL encourages students to engage in meaningful interactions with their peers, which can enhance their motivation to participate in learning activities and further develop their critical thinking abilities.

The increasing integration of PBL with other methods of experiential and active learning, particularly in the field of science education, highlights its potential as a powerful tool for promoting CT. Hallinger (2023) observed that combining PBL with other active learning strategies, such as inquiry-based learning and project-based learning, can create a more dynamic and engaging learning environment that fosters the development of critical thinking skills. This approach is particularly relevant in science education, where students are often required to apply their knowledge to solve complex, real-world problems. By integrating PBL with other experiential learning methods, educators can create opportunities for students to develop and apply their CT skills in a variety of contexts, thereby enhancing their overall learning experience and preparing them for the challenges of the 21st century.

In summary, PBL represents a promising approach for enhancing CT in higher education settings. Its emphasis on student-centered learning, problem-solving, and collaboration aligns well with the goals of CT education, making it an effective method for fostering the development of higher-order thinking skills. Despite the challenges associated with teaching CT, the evidence suggests that PBL, when implemented effectively, can provide students with the tools they need to think critically, solve complex problems, and succeed in their academic and professional endeavors. As the demand for CT continues to grow, particularly in the context of global competencies, PBL offers a valuable pedagogical approach

that can help educators meet this demand and prepare students for the future challenges.

Research Problem

The challenge of effectively enhancing critical thinking (CT) through educational interventions, particularly in higher education, remains a significant issue within the academic community. Despite the recognition of Problem-Based Learning (PBL) as a promising approach for fostering CT, inconsistencies in the reported outcomes of various studies create uncertainty about its effectiveness (Anggraeni et al., 2023). This uncertainty is compounded by the diverse contexts, methods, and research designs employed in previous studies, which makes it difficult to draw definitive conclusions about the impact of PBL on students' CT development. Therefore, a comprehensive literature review and analysis are necessary to critically evaluate the existing research and understand the factors that influence the success or failure of PBL interventions in enhancing CT.

Moreover, the lack of a standardized framework for measuring and defining CT further complicates efforts to assess the effectiveness of PBL. Different studies have utilized varied definitions and assessment tools, leading to discrepancies in their findings. This variation underscores the need for a systematic analysis that considers not only the outcomes of PBL interventions but also the underlying methodologies and contextual factors that may affect these outcomes. By examining the existing body of literature, this study aims to address these challenges, providing a clearer understanding of how PBL can be most effectively utilized to enhance CT and offering insights into the conditions under which it may be most successful.

Objectives of the Study and Novelty

The objective of this study is to conduct a thorough literature review focusing on the analysis of contexts, methods, and outcomes of previous research that has utilized Problem-Based Learning (PBL) to enhance students' critical thinking (CT). This analysis will involve identifying the various approaches used in different educational settings, examining the effectiveness of PBL interventions in improving CT, and understanding the factors that contribute to the success or limitations of these interventions.

The novelty of this research lies in its rigorous approach to synthesizing existing studies on Problem-Based Learning (PBL) and critical thinking (CT). Unlike previous reviews, this study emphasizes studies that employed experimental research methodologies, as these provide stronger evidence of causality between PBL interventions and CT outcomes (Liu & Pásztor, 2022; Suhirman & Prayogi, 2023). The analysis centers on studies that assessed the impact and effectiveness of PBL, offering a clearer understanding of how this instructional strategy influences CT development (Choi et al., 2014; Amanda et al., 2023). Furthermore, this research explores the nuanced interplay between contextual and methodological factors affecting outcomes, providing a detailed understanding of how PBL can be optimized across various educational contexts (Lonergan et al., 2022; Anggraeni et al., 2023). These insights contribute to the development of best practices for educators and enrich the broader discourse on effective teaching strategies in higher education.

METHOD

Systematic Literature Review Approach

This study employs a systematic literature review (SLR) approach to investigate the impact of Problem-Based Learning (PBL) on the development of critical thinking (CT) among students. SLR is a structured and transparent methodology designed to comprehensively analyze existing studies, evaluate patterns, assess intervention effectiveness, and synthesize findings to establish relationships—in this case, between PBL and CT. The SLR process

ensures rigor and minimizes biases by following predefined steps, as outlined by Tranfield et al. (2003): literature collection, inclusion and exclusion criteria application, contextual analysis, and synthesis of methods and results (see Figure 1). These steps provide a systematic and replicable framework for analyzing the data, enhancing the reliability and relevance of the findings to the research objectives.

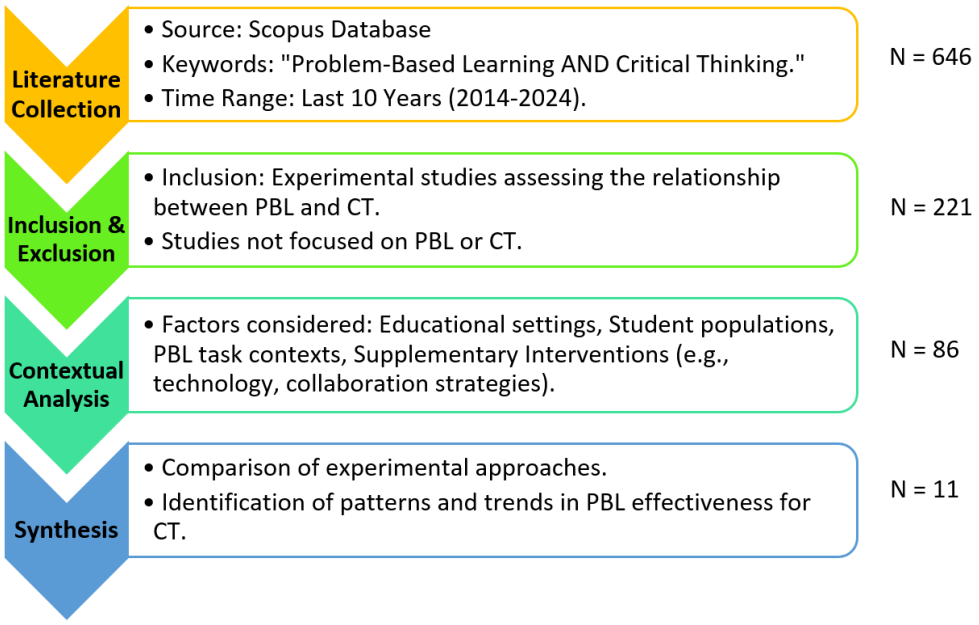

Figure 1. Systematic literature review process (Tranfield et al., 2003)

The SLR approach is particularly well-suited to addressing the research question, as it facilitates the integration of diverse methodologies and contexts. By focusing on experimental studies, this review prioritizes evidence with a higher level of reliability, enabling a robust analysis of the causal relationship between PBL interventions and CT outcomes. Additionally, the structured approach allows for the identification of trends, gaps, and areas for further exploration within the broader field of active learning and CT development. Ultimately, this methodology ensures a thorough exploration of how PBL influences CT, contributing valuable insights to educators and researchers in the field.

Literature Collection

The first phase of the review focused on systematically collecting relevant literature. The Scopus database was selected as the primary source due to its extensive repository of high-quality, peer-reviewed publications. A targeted search strategy was employed, using the keywords "Problem-Based Learning AND Critical Thinking" to identify studies directly aligned with the research objectives. This approach ensured that the review captured a broad range of studies examining PBL's impact on CT development across various educational contexts.

As summarized in Figure 1, the initial search yielded 646 studies, which represented a diverse pool of research related to PBL and CT. To ensure the relevance of the findings to contemporary educational practices, the search results were refined by applying a temporal restriction to include only studies published in the last ten years (2014–2024). This restriction allowed the review to focus on current methodologies and interventions reflective of modern teaching practices.

In addition to the temporal restriction, studies were filtered based on their research design, with a specific emphasis on experimental studies. This emphasis was critical, as

experimental research provides stronger evidence of causality between PBL interventions and CT outcomes compared to observational or descriptive studies. After applying these preliminary criteria, the pool of studies was reduced to 221 publications, forming the basis for the subsequent stages of the review.

Inclusion and Exclusion Criteria

The next step involved applying detailed inclusion and exclusion criteria to refine the dataset further. The inclusion criteria prioritized studies that explicitly employed experimental methodologies, such as randomized controlled trials, quasi-experimental designs, or pre-experimental designs, as these designs offer the most reliable evidence of causality. Additionally, the studies needed to focus on the relationship between PBL and CT, ensuring alignment with the research objectives.

Conversely, studies were excluded if they did not explicitly focus on PBL or CT, or if they were purely descriptive in nature without assessing the impact of PBL interventions. This filtering process ensured that the review analyzed only high-quality and relevant research, significantly narrowing the pool to 86 studies. These selected studies were then subjected to further evaluation based on their methodological rigor, relevance, and quality of evidence, ensuring a robust foundation for the analysis.

Contextual Analysis

The contextual analysis phase examined the specific conditions under which PBL interventions were implemented in the selected studies. This analysis focused on several key factors that influence the effectiveness of PBL, including educational settings, student populations, PBL task contexts, and supplementary interventions. These variables provided valuable insights into the adaptability and applicability of PBL across diverse learning environments.

For example, the review considered variations in classroom dynamics, such as the size and composition of student groups, which can significantly influence collaboration and engagement during PBL tasks. Cultural contexts were also analyzed, as differences in educational norms and practices across regions may affect the implementation and outcomes of PBL interventions. Additionally, the availability of resources, such as access to trained facilitators or technological tools, was examined as a potential limiting or enabling factor.

The contextual analysis also explored the role of interventions accompanying PBL, such as the use of mobile applications, argumentation frameworks, or collaborative learning strategies. These elements were identified as critical in shaping the effectiveness of PBL, as they enhance student engagement and support deeper learning processes. After completing this phase, the pool of studies was further refined to 11 high-quality publications, representing the most rigorous and impactful research on the topic.

Synthesis of Methods and Results

The final phase of the review involved synthesizing the methods and results of the selected studies to draw comprehensive conclusions about the overall effectiveness of PBL. This synthesis focused on comparing the experimental designs and outcomes across studies, identifying patterns, trends, and commonalities that provide insights into how PBL strategies influence CT development.

Particular attention was given to the diversity of approaches employed in the studies, including variations in task design, intervention duration, and the integration of supplementary strategies. By synthesizing these elements, the review identified several factors that contribute to PBL's effectiveness, such as the inclusion of interdisciplinary

approaches, the integration of argumentation frameworks, and the use of technology to facilitate learning. These findings offer a nuanced understanding of how PBL can be optimized to enhance CT, providing valuable guidance for educators and researchers.

The synthesis also highlighted gaps and areas for further exploration, such as the need for more longitudinal studies to assess the sustained impact of PBL on CT development. Additionally, the variability in outcomes across different contexts underscores the importance of tailoring PBL implementations to specific learner needs and educational settings. By addressing these gaps, future research can further refine and enhance the use of PBL as a tool for fostering critical thinking in education.

RESULTS AND DISCUSSION

The systematic literature review conducted in this study aimed to evaluate the effectiveness of Problem-Based Learning (PBL) in enhancing critical thinking (CT) among students. Through a comprehensive analysis of selected studies, various outcomes and influencing factors were identified, shedding light on the conditions under which PBL most effectively promotes the development of CT. The synthesis of these studies not only highlights the overall impact of PBL on CT but also reveals the nuances in its application across different educational settings.

The discussion that follows presents the findings from the analyzed articles, focusing on the reported effectiveness of PBL interventions, the contexts in which they were implemented, and the methodological approaches employed. These findings are crucial for understanding the varying degrees of success observed in different studies and for identifying best practices in the use of PBL to foster CT. The results of this analysis, which provide a detailed overview of the impact of PBL on the development of CT among students, are summarized in Table 1.

Table 1. Summary of studies analyzing the impact of PBL on the development of CT among students

Author(s)	Research context	Method	Results	Critical analysis
(Choi et al., 2014)	PBL vs. Traditional Lecture	Experimental research: A quasi-experimental non-equivalent group pretest-posttest design.	There is a positive correlation between CT, problem-solving, and self-directed learning. PBL enhances these three components; however, there is no significant difference compared to traditional teaching.	PBL showed trends toward improving CT, problem-solving, and self-directed learning, though results were statistically non-significant. Factors such as insufficient program duration and students' limited prior exposure to group learning likely influenced outcomes.

Author(s)	Research context	Method	Results	Critical analysis
(Anazifa & Djukri, 2017)	PBL vs. PjBL	Experimental research: Quasi experiment using non-equivalent control-group design.	Both PBL and PjBL significantly impact students' CT abilities. There is no difference in the effect of PBL and PjBL on students' critical thinking.	PBL and Project-Based Learning significantly improved CT and creativity. Limited by reliance on group dynamics, affecting consistency in skill development.
(Jatmiko et al., 2018)	OR-IPA (Orientation, Representation, Investigation, Presentation, Analysis) vs. PBL vs. Conventional Learning.	Experimental research: True Experiment with Randomized Subject Control-group Pre-test and Post-test.	OR-IPA and PBL models are effective in enhancing CT, while conventional models are not. OR-IPA is more effective than PBL.	OR-IPA outperformed PBL in improving CT among pre-service physics teachers, attributed to its multi-representation approach. However, low inference gains and traditional teaching reliance may have hindered broader impact.
(Ismail et al., 2018)	Mobile PBL application (DicScience)	Experimental research: pre-experimental study involving a treatment group.	The application can have a positive effect on students' critical thinking skills.	A mobile PBL app significantly improved CT in students. Effective integration of real-life scenarios and interactive elements were critical; however, the short intervention duration constrained deeper CT development.
(Waite et al., 2020)	PBL vs. Non PBL	Retrospective cohort study.	Significant difference in CT performance between PBL and non-PBL interventions, with PBL consistently supporting students' CT performance.	PBL improved performance in concurrent pharmacy courses but showed no significant benefits for subsequent non-PBL courses. Discrepancies across cohorts and reliance on non-PBL grading measures influenced findings.

Author(s)	Research context	Method	Results	Critical analysis
(Akhdinirwanto et al., 2020)	PBL with Argumentation (PBLA)	Experimental research: pre-experimental study with a pretest-posttest design.	PBLA is effective in improving students' CT. The improvement in CT is moderate.	PBLA enhanced CT in students by integrating Toulmin Argumentation. Challenges arose in student unfamiliarity with argument structures and limited time for practice.
(Lonergan et al., 2022)	Efficacy of PBL	Experimental research: Quasi-experimental study.	PBL is effective in knowledge development, especially for high-achieving students, but is less effective in developing problem-solving skills.	PBL enhanced knowledge acquisition in secondary students but showed minimal gains in problem-solving and self-regulation. Diverse learner readiness and insufficient scaffolding were key limiting factors.
(Hidajat, 2023)	Conventional PBL (PBCL) vs. creative PBL (CPBL)	Experimental research: Quasi-experimental study.	CPBL is more effective than PBCL in maximizing students' self-regulated learning abilities.	CPBL was significantly more effective than PBCL in enhancing self-regulation skills among students. CPBL's use of complex, realistic problems fostered creativity, though variability in group dynamics affected consistency.
(Amanda et al., 2023)	Complexity Science-PBL (CS-PBL)	Experimental research: Quasi-experimental with nonequivalent pre-test-post test control group design.	Complexity Science-PBL (CS-PBL) can improve critical thinking and problem-solving skills.	CS-PBL was more effective than PBL in enhancing CT and problem-solving, credited to interdisciplinary integration. Limited time for concept mastery posed constraints.

Author(s)	Research context	Method	Results	Critical analysis
(Rafie-Papkiadeh et al., 2024)	PBL vs. Task-based Learning (TBL)	Experimental research: Quasi-experimental study.	Task-Based Learning (TBL) is more effective than PBL in improving students' decision-making abilities.	TBL outperformed PBL in improving knowledge and decision-making. Real-world task immersion and structured phases contributed to TBL's success. Challenges included limited PBL engagement and uneven student readiness.
(Lestari et al., 2024)	PBL with iSpring assisted inquiry method	Experimental research: Pre-tes post-test one group design.	PBL with iSpring assisted inquiry method can improve students' CT skills.	Problem-Based Learning with iSpring facilitated inquiry improved CT. However, reliance on digital tools created accessibility issues for some students

The results from the systematic literature review reveal a diverse range of findings regarding the impact of PBL on developing CT among students. The studies summarized in Table 1 highlight both the effectiveness and limitations of PBL across various educational contexts, emphasizing the complexity of implementing PBL as a universal strategy for enhancing CT. For instance, Choi et al. (2014) demonstrated that while PBL positively correlated with CT, problem-solving, and self-directed learning, its outcomes were not significantly different from traditional teaching methods. This suggests that although PBL can foster higher-order thinking skills, its superiority over conventional approaches may not always be evident. These mixed results underscore the need for a nuanced understanding of how PBL interacts with different teaching environments and student populations to effectively enhance CT, necessitating further exploration into the specific conditions that maximize PBL's benefits.

Anazifa and Djukri (2017) conducted a comparative study between PBL and Project-Based Learning (PjBL), revealing that both methods significantly enhanced students' CT abilities, but with no significant difference between them. This finding suggests that while PBL is effective, other active learning strategies, such as PjBL, may offer similar advantages in fostering CT. This aligns with broader literature that underscores the importance of active learning in cultivating CT, as supported by researchers like Anggraeni et al. (2023) and Sarkingobir & Bello (2024). These results indicate that while PBL is a valuable tool for developing CT, it is not the only method capable of achieving these outcomes, highlighting the importance of considering various active learning approaches that may be equally effective depending on the educational context and student needs.

Jatmiko et al. (2018) compared three instructional models: OR-IPA, PBL, and conventional learning. The study found that both OR-IPA and PBL were effective in

enhancing CT, whereas conventional learning did not yield similar results. Notably, OR-IPA was more effective than PBL, suggesting that while PBL is a strong method for developing CT, other instructional strategies that emphasize open-ended inquiry and realistic problem-solving, such as OR-IPA, may offer even greater benefits. This finding highlights the potential for integrating or even preferring alternative models to PBL in certain educational settings, particularly where inquiry-based learning is central to the curriculum. It also points to the importance of further research into the conditions that make PBL or its alternatives most effective in promoting CT.

Ismail et al. (2018) explored the impact of a mobile PBL application, DicScience, through a pre-experimental study. The results indicated that the application had a positive effect on students' CT skills, demonstrating the potential of integrating technology with PBL to enhance its effectiveness. This study suggests that the use of mobile technology in PBL can promote self-directed learning and critical analysis, aligning with modern educational needs where digital literacy and technological integration are increasingly important. The positive outcomes of DicScience indicate that technology-enhanced PBL could be a significant step forward in education, offering new ways to engage students and facilitate CT development. These findings highlight the growing relevance of digital tools in education and the potential for mobile applications to complement traditional PBL strategies effectively.

Waite et al. (2020) conducted a retrospective cohort study comparing the effectiveness of PBL with non-PBL interventions in fostering CT among students. The results showed a significant difference in CT performance, with students exposed to PBL outperforming those who were not. This study underscores PBL's role in consistently supporting CT development, particularly in settings where students engage deeply with complex, real-world problems. These findings are crucial as they validate PBL's effectiveness across different educational contexts and reinforce the value of problem-solving and analytical reasoning skills in CT development. The consistency of these outcomes across various studies suggests that PBL is a reliable method for enhancing CT, especially when implemented with a strong emphasis on active learning and real-world application.

In the study by Akhdinirwanto et al. (2020), the effectiveness of PBL combined with an argumentation component (PBLA) was investigated through a pre-experimental study. The results demonstrated that PBLA was effective in improving students' CT, with the enhancement categorized as moderate. This suggests that augmenting PBL with specific strategies, such as argumentation, can further enhance its impact on CT. The combination of PBL with argumentation aligns with theoretical frameworks that emphasize the importance of reasoning and reflective inquiry in CT development (Suhirman & Prayogi, 2023). These findings indicate that integrating additional cognitive processes into PBL can make the method more robust, enhancing students' ability to critically evaluate and reflect on complex issues.

Lonergan et al. (2022) conducted a quasi-experimental study to evaluate the efficacy of PBL, finding that while it was effective in enhancing knowledge development, it was less successful in developing problem-solving skills. This highlights a potential limitation of PBL, suggesting that while it can foster CT, its effectiveness in other related skills, such as problem-solving, may vary depending on the instructional design and the characteristics of the student population. These findings are significant as they indicate that while PBL is generally beneficial, its impact may be limited if not properly tailored to the specific needs and skills of students. Further research is needed to explore how PBL can be adapted to better support problem-solving and other related cognitive skills.

In a study by Hidajat (2023), the effectiveness of conventional PBL (PBCL) was compared with a more creative version (CPBL). The results showed that CPBL was more effective in enhancing students' self-regulated learning abilities, suggesting that incorporating creative elements into PBL can enhance its impact. This finding is important as it highlights the adaptability of PBL and the potential benefits of integrating creativity into the learning process. The success of CPBL in fostering self-regulation, a critical component of CT, suggests that PBL's effectiveness can be significantly improved by including innovative and creative approaches. This aligns with broader educational goals of fostering not just critical thinking, but also creativity and autonomy in students.

Amanda et al. (2023) investigated the use of CS-PBL and found that it effectively improved both CT and problem-solving skills. This study used a quasi-experimental design and suggests that incorporating complexity science principles into PBL offers a more nuanced method of fostering CT. The integration of interdisciplinary elements into PBL, as seen in CS-PBL, highlights the potential for such approaches to yield significant educational benefits, particularly in enhancing students' ability to navigate and understand complex systems. These findings reinforce the value of interdisciplinary education and suggest that PBL, when combined with other innovative approaches, can be an even more powerful tool for developing critical and analytical skills in students.

Finally, the study by Rafie-Papkiadeh et al. (2024) compared PBL with TBL and found that TBL was more effective in enhancing students' decision-making abilities. This result, along with Lestari et al. (2024) showing that PBL with an iSpring-assisted inquiry method significantly improved students' CT skills, suggests that while PBL is valuable, other instructional strategies may be better suited for specific cognitive skills. These findings highlight the importance of selecting the appropriate instructional method based on the desired learning outcomes. The varied effectiveness of PBL in different studies underscores the need for a nuanced approach to education, where PBL is one of several tools available to educators, each with its strengths and limitations depending on the educational context and goals.

PBL enhances CT by creating an educational environment where students actively engage with complex, real-world problems, fostering the development of higher-order cognitive skills such as analysis, synthesis, and evaluation. Through its structured process, PBL encourages students to critically analyze problems, set goals, gather resources, synthesize ideas, and reflect on their problem-solving experiences. Studies have shown that PBL's student-centered approach effectively promotes CT by requiring students to apply critical reasoning and collaborative learning in solving ill-defined, open-ended problems (Suhirman & Prayogi, 2023). This method is particularly effective in environments where students are motivated to explore diverse perspectives and refine their reasoning through dialogue with peers and instructors (Savery, 2006). Additionally, the integration of technology and interdisciplinary elements, such as mobile applications and complexity science principles, further enhances the impact of PBL on CT by providing innovative ways to engage students and address multifaceted issues (Ismail et al., 2018; Amanda et al., 2023). However, the effectiveness of PBL can vary depending on the context, instructional design, and additional components integrated into the PBL framework, highlighting the need for tailored approaches that consider the specific needs and cognitive skills of students (Lonergan et al., 2022; Hidajat, 2023). Ultimately, while PBL is a powerful tool for fostering CT, its success depends on how it is implemented and adapted to meet the diverse challenges of different educational settings.

The systematic review highlights several factors influencing the varying effectiveness of PBL in developing critical thinking CT across diverse educational settings. A key determinant

appears to be the duration and structure of PBL programs. For instance, studies like Choi et al. (2014) and Ismail et al. (2018) suggest that insufficient program duration and a lack of prior exposure to group learning constrained the development of CT and problem-solving skills. While PBL's impact was positive, these limitations underscore the need for well-designed, longer-duration interventions that allow students sufficient time to adapt to PBL's collaborative and self-directed approach. Similarly, interventions that leverage real-world scenarios, such as DicScience, showed promise but were constrained by the brevity of their implementation periods.

Another significant factor influencing PBL outcomes is the integration of supplementary instructional components. The inclusion of elements like Toulmin Argumentation (PBLA) and iSpring-assisted inquiry methods enhanced PBL's effectiveness by fostering structured reasoning and deeper engagement with the learning material (Akhdinirwanto et al., 2020; Lestari et al., 2024). However, challenges arose from students' unfamiliarity with these new approaches, emphasizing the importance of preparatory training to build foundational skills. Studies integrating interdisciplinary principles, such as Amanda et al. (2023), further demonstrated that combining PBL with complexity science enhanced its impact on CT and problem-solving. These findings suggest that PBL's adaptability to include innovative methodologies is a critical factor in its success.

The context and learner characteristics also play a crucial role in PBL's effectiveness. Lonergan et al. (2022) reported that PBL was particularly beneficial for high-achieving students but less effective for those with diverse learning readiness or weaker problem-solving foundations. Similarly, group dynamics and collaboration, as seen in Anazifa and Djukri (2017) and Hidajat (2023), influenced consistency in skill development. When group interactions were not carefully scaffolded or facilitated, students struggled to engage meaningfully, impacting their overall learning outcomes. These results highlight the need for tailored scaffolding and targeted support to ensure all students benefit from PBL, irrespective of their initial readiness or learning styles.

Finally, comparisons between PBL and alternative instructional strategies reveal critical insights into PBL's relative strengths and limitations. For example, Task-Based Learning (TBL) outperformed PBL in fostering decision-making skills due to its structured phases and task immersion (Rafie-Papkiadeh et al., 2024). Similarly, OR-IPA's multi-representation approach demonstrated greater efficacy in enhancing CT compared to PBL (Jatmiko et al., 2018). These findings indicate that while PBL is effective, it may not always be the optimal choice for specific outcomes. By integrating elements from complementary methods or selectively applying PBL in contexts where it aligns with educational objectives, educators can maximize its potential while addressing its inherent limitations.

CONCLUSION

The systematic literature review confirms that PBL is a robust and versatile instructional strategy for enhancing CT among students. By emphasizing active, student-centered learning and problem-solving, PBL supports the development of key cognitive skills such as analysis, synthesis, and evaluation. The findings underscore that while PBL is broadly effective, its success is influenced by several factors, including the educational context, the design of instructional interventions, and the integration of complementary strategies. For instance, studies show that PBL's impact is amplified when combined with argumentation frameworks, interdisciplinary approaches, or technological tools, such as mobile applications. These enhancements enable deeper engagement, foster reflective thinking, and align PBL with contemporary educational needs. However, inconsistent outcomes across studies suggest that

PBL should not be implemented as a uniform strategy. Instead, its flexible framework should be tailored to specific learner needs, educational goals, and institutional capacities to maximize its effectiveness.

A critical analysis of the reviewed studies highlights the importance of addressing contextual and methodological variations to optimize PBL's impact. Factors such as program duration, student readiness, and the scaffolding of collaborative processes significantly influence outcomes. Short-duration interventions or inadequate preparation often limit the depth of CT development, as seen in some studies. Furthermore, while PBL thrives in fostering higher-order cognitive skills, its comparative effectiveness against alternative methods like TBL or OR-IPA may vary for specific objectives, such as decision-making or multi-representational learning. The evidence also suggests that integrating innovative approaches, such as CPBL, can significantly enhance student engagement and self-regulation, addressing limitations in traditional PBL models. Ultimately, the findings advocate for a nuanced and adaptive approach to PBL, leveraging its strengths while incorporating tailored strategies to overcome its limitations, ensuring its efficacy in diverse educational contexts.

LIMITATION

This systematic review is limited by the variability in study designs, contexts, and methodologies of the analyzed research, which complicates direct comparisons of PBL's effectiveness across different settings. The reliance on quasi-experimental and pre-experimental designs in several studies introduces potential biases and limits the generalizability of findings. Additionally, the heterogeneity in intervention durations, student populations, and the integration of supplementary components such as technology or argumentation restricts the ability to establish standardized best practices for implementing PBL. The review also highlights a lack of longitudinal studies that could assess the sustained impact of PBL on critical thinking development over time, leaving gaps in understanding its long-term efficacy.

RECOMMENDATION

Future research should prioritize the use of robust experimental designs, such as randomized controlled trials, to provide more definitive evidence of PBL’s effectiveness in fostering critical thinking. Longitudinal studies are also recommended to evaluate the sustained impact of PBL on cognitive skills and learning outcomes. Additionally, researchers should explore innovative integrations of PBL with emerging technologies, interdisciplinary approaches, and creative frameworks to enhance its adaptability and effectiveness. Educators and policymakers are encouraged to adopt a tailored approach, aligning PBL implementations with specific learner needs, institutional capacities, and desired outcomes, while addressing the identified limitations through adequate training, scaffolding, and program design refinements.

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Declaration of Interest

The authors declare no conflict of interest..

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