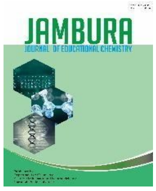
Jambura Journal of Educational Chemistry
Volume 8 Issue 2, August 2026
p-ISSN: 2655-7606, e-ISSN: 2656-6427
Journal Homepage: http://ejurnal.ung.ac.id/index.php/jjec



A Systematic Literature Review of Problem-Based Learning in Chemistry Education: Advancing Critical Thinking and Motivation

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Article Info

Article history:
Received: 28-06-2026
Revised: 18-07-2026
Accepted: 19-07-2026
Available online: 01-08-2026

Keywords:
Chemistry Education; Critical Thinking; Learning Motivation; Problem-Based Learning (PBL); PRISMA 2020; Systematic Literature Review (SLR)

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Abstract

This systematic review evaluates the directional trends, pedagogical benefits, and execution challenges of Problem-Based Learning (PBL) within chemistry education over the past five years, emphasizing its impact on student motivation and critical thinking. Operating via a Systematic Literature Review (SLR) anchored in the PRISMA framework, this study synthesizes recent empirical data. The findings reveal a pronounced upward trajectory in PBL adoption, particularly accelerating after 2020. Empirically, the model consistently advances critical thinking, analytical reasoning, problem-solving, and scientific argumentation, while concurrently elevating academic achievement and laboratory performance. It also refines student research skills, scientific attitudes, and creative thinking. Concurrently, PBL substantially amplifies learning motivation, evidenced by heightened student interest, engagement, positive attitudes, and readiness. However, certain cases show that advancements in motivation and problem-solving do not always significantly surpass alternative instructional methods, highlighting the influence of contextual variables. Practically, implementation frequently relies on innovative modules like E-LKPD and e-modules, collaborative frameworks, technology, and structured scaffolding. Conversely, prominent challenges persist, including scarce target materials, varying facilitator capacity, learner resistance, and resource limitations. By consolidating empirical insights into how PBL mediates critical thinking and motivational growth, this inquiry enriches constructivist theory in chemistry pedagogy and delivers an integrative model for 21st-century education. While PBL remains a valuable pedagogical strategy, its successful deployment necessitates sustained professional development for educators alongside deeper exploration into its interplay with student learning styles and technology integration across diverse contexts.

How to Cite: Nurpialawati, I., & Salirawati, D. (2026). A Systematic Literature Review of Problem-Based Learning in Chemistry Education: Advancing Critical Thinking and Motivation. *Jambura J. Educ. Chem.*, 8(2), 267-278. https://doi.org/10.37905/jjec.v8i2.40137

1. INTRODUCTION

Contemporary demands for instructional quality improvement in chemistry education orient toward stimulating higher-order thinking skills while simultaneously bolstering student intrinsic motivation. Conventional chemistry teaching methods are often deemed inadequate in bridging critical reasoning and complex problem-solving competencies that are essential for current student needs. Consequently, the adoption of innovative pedagogical frameworks has become a clear urgency to shift traditional paradigms toward an interactive, applicable, and contextual learning climate.

Problem-Based Learning (PBL) emerges as a prospective alternative methodology in transforming chemistry pedagogy. By presenting authentic problems, this student-centered orientation encourages autonomous or collaborative inquiry to trigger deep cognitive processes. Numerous scientific inquiries confirm the significant impact of PBL on both affective and cognitive student domains. The stimulation of critical thinking skills is a tangible outcome frequently verified

https://doi.org/10.37905/jjec.v8i2.40137

through the internalisation of this model (Shiddiqi & Setiyawan, 2024; Ee et al., 2023). Aligned with these findings, student enthusiasm and active classroom engagement in chemistry are also substantially elevated through problem-based instructional exposure (Winarti et al., 2024; Suwono et al., 2022).

Nevertheless, the practical dissemination of PBL within the chemical discipline is not without operational challenges. A number of studies highlight hurdles in curriculum restructuring, time management constraints, and adequate teacher readiness competencies (Jusniar et al., 2024). Supporting facilities and academic infrastructure limitations also frequently restrict the efficiency of executing PBL syntax. Furthermore, fluctuations in the success rate of this model are still detected, where the performance of PBL in several cases exhibits inconsistency that is heavily influenced by specific local contextual variables (Hafsah et al., 2024; Balac & Özoğul, 2024). Methodological variations and diverse research implementation environments across studies are identified as underlying factors for these diversified outcomes.

To date, a significant research gap persists regarding a structured, comprehensive mapping of the recent trends, advantages, and tactical barriers of PBL interventions in chemistry education. Unifying empirical findings from primary literature is crucial to present a holistic conceptualisation and project future research trajectories. Through a systematic review, macro-level correlations and patterns that might be overlooked in individual studies can be precisely identified. This inquiry adopts the Systematic Literature Review (SLR) methodology to synthesize the scattered empirical evidence.

This investigation aims to thoroughly examine the contemporary scientific literature regarding Problem-Based Learning (PBL) within the domain of chemistry education. The scope of this review encompasses the application trends, benefits, and implementation constraints encountered over the last five years. The systematic evaluation process is guided by four primary research questions: (1) How has the application trend of Problem-Based Learning (PBL) evolved within the context of chemistry education over the past five years? (2) What are the main contributions of implementing Problem-Based Learning (PBL) toward the development of critical thinking and student motivation in chemistry education? (3) What are the specific constraints or challenges encountered when implementing Problem-Based Learning (PBL) in chemistry education? (4) Which research areas still present gaps that can be further explored regarding Problem-Based Learning (PBL) in chemistry education?

2. METHOD

This inquiry adopts a systematic literature review (SLR) methodology aligned with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Utilizing this structured framework guarantees a transparent and replicable article selection procedure executed across four distinct operational phases: identification, screening, eligibility, and inclusion.

Comprehensive literature extraction was performed across the Scopus, ScienceDirect, Google Scholar, and DOAJ databases. To isolate highly pertinent literature, boolean search strings and specific keyword combinations were deployed, including: "Problem-Based Learning" AND "Chemistry Education" AND "Critical Thinking"; "Problem-Based Learning" AND "Chemistry Education" AND Motivation; ("Problem-Based Learning" OR PBL) AND "Chemistry Education" AND ("Critical Thinking" OR Motivation); as well as "Problem-Based Learning" AND "Chemistry Education" AND ("Critical Thinking" AND Motivation). The scope of analysis was strictly limited to scholarly papers published between 2022 and 2026.

The retrieved articles were rigorously evaluated against predefined inclusion and exclusion parameters. These rigorous filtering benchmarks were established to guarantee that only the most contextually relevant and high-quality scientific contributions were integrated into the final review synthesis.

Table 1. Inclusion and exclusion

Selection Parameter	Inclusion Criterion	Exclusion Criterion
Publication Year	Scholarly works published within the timeframe of 2022 to 2026.	Documents published outside the designated 2022–2026 window.
Document Type	Peer-reviewed scientific journal articles exclusively.	Non-journal publications, including textbooks, book chapters, conference proceedings, theses,

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Selection Parameter	Inclusion Criterion	Exclusion Criterion
		dissertations, blog posts, news reports, and opinion pieces.
Language	Manuscripts composed entirely in English.	Literature written in languages other than English.
Text Accessibility	Availability of the complete full-text manuscript for analysis.	Abstracts-only or articles with inaccessible full-text documents.
Core Topic Relevancy	Studies directly investigating the execution of Problem-Based Learning (PBL) inside chemistry education environments.	Research unrelated to either Problem-Based Learning methodologies or chemical education frameworks.
Focus Dimension Relevancy	Investigations addressing the explicit influence of PBL on student critical thinking capabilities, learning motivation, or both.	Papers failing to examine either motivational dynamics or critical thinking skills within the scope of the PBL intervention.

The systematic selection process commenced with the initial identification phase based on the PRISMA guidelines. A total of 549 records were gathered from the designated databases, consisting of 233 from Scopus, 139 from ScienceDirect, 100 from Google Scholar, and 77 from DOAJ. Subsequently, the removal of 165 duplicate entries narrowed the pool down to 384 unique documents. These remaining papers underwent title and abstract screening, which led to the exclusion of 333 irrelevant studies and left 51 manuscripts for full-text eligibility assessment.

During this stage, an additional 35 papers were discarded for failing to strictly satisfy the predetermined inclusion benchmarks. This rigorous filtering workflow ultimately yielded a final cohort of 16 peer-reviewed articles designated for comprehensive synthesis.

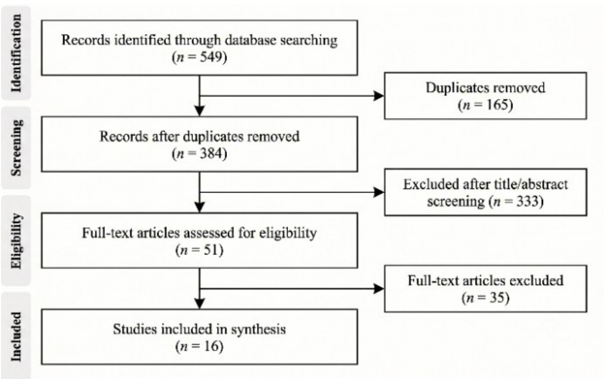

Figure 1. The PRISMA filtration pathway

To guarantee empirical rigor, the quality of each included study was scrutinized across five criteria: topical alignment, methodological clarity, sample and data transparency, outcome coherence, and research contribution. Each parameter was evaluated using a three-point scale ranging from 1 (low quality) to 3 (high quality), with low-scoring papers excluded from the final selection. The 16 articles chosen for the final synthesis demonstrated an optimal average quality score of 3 out of 3.

Data extraction was systematically performed on the selected literature to gather critical operational details. The extracted parameters comprised the primary research objectives, methodological designs, specific PBL implementation contexts, student demographics, evaluation instruments, and explicit findings concerning critical thinking and motivational outcomes. The compiled dataset was subsequently interpreted through thematic synthesis, allowing for the identification of recurring patterns, core themes, and conceptual interactions to build a holistic understanding of PBL dynamics in chemistry pedagogy.

3. RESULT AND DISCUSSION

3.1. Result

The PRISMA framework guided the systematic selection workflow deployed in this literature assessment. An initial extraction phase identified 549 potentially relevant manuscripts across the specified digital repositories. Following the removal of 165 duplicate entries, a refined cohort of 384 unique studies was established. A preliminary screening of titles and abstracts led to the immediate exclusion of 333 contextually irrelevant papers, leaving 51 articles to undergo comprehensive full-text eligibility appraisal. During this rigorous evaluation stage, 35 papers were discarded for failing to fulfill the explicit inclusion criteria, culminating in a definitive sample of 16 high-quality articles for formal synthesis.

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Table 2. Article characteristic

Investigation Aspect	Synthesized Findings
Final Article Cohort	16 primary studies underwent definitive thematic evaluation.
Temporal Distribution	Scholarly literature published within the 2022–2026 window.
Geographic Dominance	Prominent research output originating from Indonesia, Malaysia, Kazakhstan, and Nigeria.
Prevalent Methodologies	Research and Development (R&D) utilizing the 4D framework, classroom action research, qualitative descriptive approaches, Transcript-Based Lesson Analysis (TBLA), pedagogical module development, and quantitative surveys.
Core Theoretical Themes	Enhancement of student cognitive outcomes and technical skills, implications for educational supporting factors, alongside core dynamics regarding PBL execution and instructional design.

Trends of Publication

An analysis of the publication trends within the selected literature cohort reveals fluctuating annual patterns over the designated period. In 2022, the database search identified 3 highly relevant articles. This output remained completely stable into 2023, which also yielded 3 articles. A pronounced spike occurred in 2024, with annual publications doubling to a peak of 6 articles. Subsequently, production experienced a slight contraction in 2025, dropping back to 3 articles, while the initial months of 2026 accounted for just 1 article that successfully met all inclusion benchmarks.

Tabel 3. Data extraction

No.	Author (Year)	Location	Methodology	Primary Insights
1	Shiddiqi & Setiyawan (2024)	Indonesia	Classroom Action Research	Integrating the PBL model with Quizizz platforms successfully optimized student learning motivation, achieving an 83% success rate during the second cycle and showing a steady increase from the initial cycle's metric of 81.34%.
2	Winarti et al. (2024)	Indonesia	Qualitative Descriptive, Transcript-Based Lesson Analysis (TBLA)	The instructional communication ratio between instructors and students registered at 1:3 for Case-Based Methods (CBM) compared to 1:1 for the PBL approach; while CBM establishes a solid foundation for cultivating higher-order thinking skills (HOTS), PBL encourages superior peer-to-peer collaboration.
3	Ee et al. (2023)	Malaysia	Module Development, Quantitative Survey	The formulated PBL instructional module attained a high validation consensus (95.83%) regarding its educational targets, structural alignment, and linguistic clarity, validating PBL as a highly effective pedagogical tool for chemical education.
4	Jusniar et al. (2024)	Indonesia	Analytical Descriptive, Quasi-Experimental Design	Analytical assessments revealed an upgrade in student critical thinking faculties following the PBL treatment, yielding a moderate-category mean normalized gain (N-gain) of 0.59.
5	Hafsah et al. (2024)	Indonesia	Research and Development (R&D) via the 4D Model	The developed PBL-driven electronic student worksheets (E-LKPD) exhibited exceptional expert validity and generated positive student feedback, while driving significant expansions in student motivation (45%) and diagnostic problem-solving capacities (75%).
6	Suwono et al. (2022)	Indonesia	Quasi-Experimental with Non-Equivalent Control Group Pretest-Posttest Design	Learners subjected to the modified problem-based learning framework (M-PBL) exhibited superior scientific argumentation competencies and critical thinking capacities, showing pronounced development through this specific instructional platform.
7	Wahyudiati (2022)	Indonesia	Quasi-Experimental with Unequal Control Group Pretest-Posttest Design	The problem-based learning framework exerted a prominent 28% variance contribution toward shaping students' scientific attitudes and critical thinking skills, with the capacity to synthesize perspectives toward scientific inquiry emerging as the most dominant learner attribute.

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No.	Author (Year)	Location	Methodology	Primary Insights
8	Asmi et al. (2024)	Indonesia	Research and Development (R&D) via the ADDIE Model	The structured e-module demonstrated high feasibility benchmarks during expert and practitioner reviews, substantially advancing critical thinking capacities with a moderate N-gain score of 0.48 and a 55% average score elevation into the critical performance classification.
9	Ernawati et al. (2023)	Indonesia	Explanatory Sequential Mixed-Methods (Descriptive, T-Test, Simple Linear Regression)	Distinct variations in student learning interest emerged when comparing standard PBL to scaffolded PBL variants, with learning interest exerting a direct, statistically verifiable influence on the creative thinking capacities of students within the problem-based environment.
10	Chaniago et al. (2025)	Indonesia	Quasi-Experimental with Pretest-Posttest Control Group Design	No statistically significant variance was observed between the PBL and discovery learning treatments concerning motivation or problem-solving gains; however, student learning styles heavily dictated both outcomes, with PBL yielding minor contributions separate from any learning style interactions.
11	Perdima et al. (2025)	Indonesia	True Experimental with Pretest-Posttest Control Group Design	While both the PBL framework and the Teaching Personal and Social Responsibility (TPSR) model successfully enhanced student accountability metrics and learning motivation, the TPSR cohort exhibited a more pronounced increase compared to its PBL counterpart.
12	Madybekova et al. (2026)	Kazakhstan	Quasi-Experimental Design	The active PBL cohort achieved significantly higher post-test outcomes across all measured educational benchmarks compared to the control group, illustrating substantial growth in theoretical comprehension, practical laboratory execution, academic research capabilities, motivation, and active student engagement.
13	Omeh & Ayanwale (2025)	Nigeria	Quasi-Experimental with Non-Equivalent Pretest-Posttest Control Group Design	Deploying artificial intelligence within a problem-based learning framework resulted in major advancements in student academic performance, classroom motivation, and active participation compared to traditional PBL methods.
14	Balac & Özoğul (2024)	Undisclosed	Evaluative Mixed-Methods Case Study	Implementing targeted PBL modules yielded statistically significant growth in image critique proficiencies among radiography students, leaving participants feeling better equipped for professional critique tasks while endorsing collaborative peer work as an excellent mechanism for skill practice.
15	Enawaty (2023)	Indonesia	Research and Development (R&D) via the 4D Model	The developed PBL-based electronic basic chemistry module (E-Kimia Dasar) achieved an exceptional expert feasibility assessment of 95.625%, which was strongly mirrored by a positive student acceptance index of 78.03%.
16	Su (2022)	Taiwan	Mixed Quantitative & Qualitative Design	Students enhanced their scientific cognitive problem-solving capabilities while exhibiting robust logical reasoning and activation skills, with descriptive statistical metrics revealing highly optimistic learning dispositions toward cross-disciplinary PBL applications and new AI knowledge domains.

Core Emphases in the Synthesized Literature

The thematic synthesis of the gathered literature highlights several distinct conceptual domains regarding the execution of problem-based learning (PBL) within chemical education frameworks. First, the framework demonstrates a highly dependable capacity to expand student cognitive capabilities and technical skills. Deploying this educational model successfully sharpens analytical reasoning, problem-solving proficiencies, critical thinking faculties, and scientific discourse. Concurrently, it drives substantial gains in traditional academic metrics, structural theoretical knowledge, concrete laboratory operations, and formal research competencies, alongside nurturing robust scientific mindsets and creative thinking dimensions. Isolated empirical instances, however, indicate that the explicit

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influence of this framework on diagnostic problem-solving gains does not universally yield superior statistical significance when contrasted with competing pedagogical interventions.

A secondary thematic cluster addresses the direct implications of the PBL framework on essential instructional supporting variables. Generally, the application of this method successfully bolsters student motivation, subject interest, and classroom participation, while instilling enhanced learner readiness and highly constructive learning dispositions. Students exhibit distinctly optimistic viewpoints regarding cross-disciplinary applications and the incorporation of novel technological intelligence domains within problem-based environments. Nevertheless, certain comparative investigations reveal that motivational developments triggered via this instructional path do not invariably outpace alternate educational frameworks, which occasionally deliver more pronounced motivational metrics. The final established theme concentrates on the specific dynamics of practical PBL implementation and curriculum design.

The operational execution of this student-centered model frequently centers on the design of cutting-edge pedagogical modules and media assets, such as electronic worksheets and digital modules, which consistently achieve high validation benchmarks during expert and user assessments. Furthermore, the model cultivates peer-to-peer collaboration, expands interactive dialogue between instructors and learners, and can be structurally optimized through the integration of interactive digital applications or artificial intelligence platforms. Integrating structured scaffolding techniques also serves as a crucial determinant in maximizing the instructional efficacy of the problem-based framework. Ultimately, identified research gaps and future inquiries point to the critical necessity of deeper exploration into the direct interactions between problem-based environments and individual learning styles, given that these internal preferences heavily dictate overall achievement and motivation. Future investigations must prioritize rigorous comparative assessments between this strategy and other contemporary pedagogical designs, particularly regarding problem-solving and motivational development, where alternative frameworks occasionally yield superior outcomes.

3.2. Discussion

The findings of this study reveal that the implementation of Problem-Based Learning (PBL) in chemistry education significantly enhances students' higher-order thinking skills, particularly critical thinking. Students engaged in PBL environments demonstrate stronger abilities in analyzing, evaluating, and synthesizing chemical concepts compared to those exposed to conventional lecture-based instruction. This outcome aligns with the theoretical foundation of PBL, which emphasizes learning as an active, constructive, and student-centered process (Yew & Goh, 2016).

From a cognitive perspective, the improvement in critical thinking can be attributed to the structured engagement with authentic and complex problems. These problems require students to formulate hypotheses, interpret data, and justify conclusions based on scientific reasoning. Such processes are consistent with constructivist learning theory, where knowledge is actively constructed through interaction with the learning environment (Schmidt et al., 2018). Moreover, the depth of learning achieved in PBL contexts is often associated with meaningful learning experiences rather than surface-level memorization (Dolmans et al., 2016).

In addition, the results indicate that PBL significantly promotes self-directed learning among students. Learners are required to identify their own knowledge gaps, seek relevant information, and evaluate the credibility of sources independently. This autonomy fosters lifelong learning skills and enhances students' responsibility for their own academic progress (Loyens et al., 2019). The shift from teacher-centered to student-centered learning environments encourages learners to become active participants rather than passive recipients of information.

The design of problems within the PBL framework also plays a crucial role in determining learning outcomes. Well-structured and contextually relevant problems can stimulate curiosity, engagement, and deeper understanding. Hung (2019) emphasizes that effective problem design should be aligned with learning objectives, sufficiently complex to challenge students, and relevant to real-world contexts. In this study, the integration of real-life chemistry problems successfully increased students' engagement and facilitated meaningful learning experiences. For example, studies in JJEC highlight that students exposed to PBL show higher

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engagement levels and improved conceptual understanding due to the active exploration of chemistry problems rather than passive content reception (Murtihapsari et al., 2022). This reinforces the argument that PBL not only enhances cognitive outcomes but also contributes to affective aspects such as motivation and learning interest.

Collaborative learning is another significant outcome observed in this study. Through group discussions and teamwork, students develop communication skills, argumentation abilities, and social interaction competencies. These collaborative processes enable students to exchange ideas, challenge assumptions, and co-construct knowledge. According to Savery (2015), collaboration is a fundamental component of PBL that supports both cognitive and social development.

Investigations into the application of Problem-Based Learning (PBL) inside chemistry education frameworks reveal a pronounced upward trajectory over the past five years. Academic interest in this specific instructional methodology has steadily intensified, reaching a noticeable peak in 2024, which underscores its recognition as a viable solution to contemporary educational challenges. This evolutionary trend suggests that the problem-based framework is increasingly perceived as a highly relevant strategy for navigating complex chemical concepts while fostering student competencies aligned with modern industrial and societal demands. Consequently, deploying this model carries substantial potential to revolutionize chemistry education by converting passive environments into engaging, real-world problem-solving spaces.

The systematic execution of PBL reliably advances student critical thinking proficiencies. This instructional path demonstrates clear efficacy in sharpening analytical reasoning, problem-solving capacities, and scientific discourse (Ee et al., 2023). Undergraduates subjected to problem-based environments also exhibit marked improvements in standardized academic achievement, conceptual theoretical mastery, and concrete laboratory performance (Winarti et al., 2024; Jusniar et al., 2024). Furthermore, the framework nurtures empirical research capabilities alongside the cultivation of scientific mindsets and creative thinking dimensions (Hafsah et al., 2024). Conversely, the specific impact of the problem-based model on diagnostic problem-solving gains does not universally yield superior statistical significance when contrasted directly with alternative pedagogical strategies across all literature (Chaniago et al., 2025).

Generally, the problem-based framework achieves substantial success in amplifying student learning motivation. Student subject interest and active classroom participation experience a meaningful expansion through this method (Shiddiqi & Setiyawan, 2024). The internalisation of this student-centered strategy also effectively instills proactive learner readiness and highly optimistic learning dispositions. Students formulate constructive cognitive perspectives regarding cross-disciplinary applications and the incorporation of novel artificial intelligence knowledge domains within the problem-based structure (Asmi et al., 2024). On the other hand, motivational developments triggered via this instructional path do not invariably outpace alternate educational frameworks (Wahyudiati, 2022). Certain comparative pedagogical designs can even deliver more pronounced motivational metrics under specific classroom conditions (Perdima et al., 2025).

The operational execution of Problem-Based Learning (PBL) frequently involves designing highly innovative pedagogical assets. Digital tools, such as electronic worksheets (E-LKPD) and interactive e-modules, consistently achieve exceptional validity and feasibility benchmarks during expert evaluations and student feedback assessments (Suwono et al., 2022; Ernawati et al., 2023). Furthermore, the problem-based framework fosters robust peer-to-peer collaboration and reinforces communication channels between instructors and students, thereby establishing a dynamic, highly interactive classroom climate. The integration of advanced technological solutions, including artificial intelligence platforms or immersive multimedia resources, serves to significantly maximize the overall efficacy of the instructional framework (Madybekova et al., 2026). Incorporating structured scaffolding techniques also operates as a critical determinant in supporting the execution process, ensuring that learners receive targeted intellectual guidance when navigating highly complex problem scenarios (Omeh & Ayanwale, 2025).

These empirical insights strongly validate the theoretical alignment between the PBL framework and the core tenets of constructivism, wherein students dynamically construct their conceptual understanding

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through the exploration of authentic problems. The deliberate advancement of critical thinking faculties and diagnostic problem-solving capacities perfectly reflects contemporary 21st-century educational demands, which prioritize adaptive competencies. By equipping learners with rigorous analytical and synthesis capabilities, this approach prepares them to effectively confront real-world challenges. The primary scholarly contribution of this inquiry lies in its comprehensive synthesis of empirical evidence regarding the explicit implications of PBL within chemistry pedagogy, delivering actionable guidelines for educators and curriculum developers aiming to structure highly impactful learning experiences.

Nevertheless, subsequent investigations must prioritize exploring the intricate interplay between problem-based environments and individual student learning styles. Because a learner's cognitive style can heavily dictate overall achievement outcomes and motivational levels, examining personalized adaptations within the PBL architecture remains an essential research direction (Balac & Özoğul, 2024). Conducting more rigorous comparative assessments between the problem-based framework and alternative contemporary pedagogical designs is also crucial, particularly concerning motivational development and problem-solving gains, where competing strategies occasionally demonstrate superior results. Finally, investigating the optimal environmental conditions for executing this instructional model across diverse cultural settings and institutional infrastructures will greatly enrich the existing literature and offer highly specific, practical recommendations for educators.

Problem-Based Learning (PBL) exhibits a steadily accelerating application trend within chemical education frameworks over the past five years. This pedagogical approach gains widespread recognition for its potential to successfully mitigate the constraints inherent in traditional teaching methods. The systematically reviewed literature prominently highlights the robust capability of the problem-based framework to advance student cognitive growth and technical skills, specifically within the dimension of critical thinking. Furthermore, student learning motivation, operating as a vital instructional supporting variable, experiences a substantial expansion through the execution of this model, as evidenced by heightened classroom engagement, satisfaction metrics, and subject interest in chemistry. Diverse empirical inquiries consistently report marked improvements in students' capacities to analyze, synthesize, and evaluate chemical information when actively participating in problem-based environments.

Integrating the problem-based model establishes a highly contextualized learning space, stimulates autonomous exploration, and fosters peer collaboration, which constitute core elements for nurturing essential 21st-century competencies. These educational advantages are observed across multiple institutional echelons, spanning both secondary education settings and higher education levels. The practical deployment of this student-centered strategy can be tailored to diverse instructional backgrounds, illustrating the distinct flexibility and adaptability of the methodology. By utilizing real-world problems, this student-centered workflow enables learners to construct a more profound, structured comprehension of chemical concepts. Consequently, the elevation of student intrinsic motivation stands out as one of the most prominent outcomes of this framework, which subsequently drives superior academic achievement.

The deliberate advancement of critical thinking proficiencies specifically underscores the efficacy of this strategy in shaping higher-order cognitive capabilities. The verified success of the problem-based framework in facilitating the simultaneous development of both cognitive and affective aspects confirms its status as a highly valuable pedagogical asset within modern chemistry curricula. Nevertheless, several prominent execution barriers are identified across the literature. These operational constraints include a deficit of contextually targeted instructional materials or authentic problem scenarios, insufficient preparation and capacity among educators to facilitate the process, and student resistance when transitioning away from familiar instructional routines. Additional variables, such as large class sizes, limited institutional resources, and heavy curricular demands, inject further complexity into the implementation process.

Instructors frequently require targeted professional training to design impactful problem scenarios and productively guide collaborative discussions. Students, particularly those accustomed to passive lecture-based models, require transitional periods to adapt to the high levels of autonomy and active participation demanded by the problem-based structure.

Evaluating student performance also poses a distinct challenge, necessitating comprehensive assessment instruments designed to measure not only conceptual mastery but also critical thinking faculties and motivational dynamics. These systemic hurdles can be effectively addressed through sustained professional development initiatives for teachers alongside the provision of transparent orientation guidelines for students. Concurrently, significant research gaps remain within the domain of chemistry-focused PBL, requiring deeper scholarly investigation.

Longitudinal research designs are urgently needed to evaluate the long-term implications of this pedagogical approach on knowledge retention, the sustainability of critical thinking skills, and long-term student motivation. Future inquiries must also concentrate on educational settings within developing countries, where resource limitations and unique cultural backgrounds may heavily influence the execution dynamics of the model. Policy-oriented studies could further investigate how national educational frameworks either facilitate or obstruct the widespread adoption of this methodology. Moreover, exploring the integration of this framework with cutting-edge technologies, such as interactive digital simulations and virtual reality environments, holds great promise for overcoming specific resource constraints. Conducting rigorous comparative assessments between different configurations of the model, such as Team-Based Learning or Project-Based Learning, regarding specific student outcomes represents another area requiring thorough investigation.

The engineering and validation of more comprehensive diagnostic instruments to measure critical thinking and motivation specifically within chemistry-focused problem-based environments remains a high priority. Ultimately, establishing collaborative research initiatives that unite classroom practitioners and academic researchers will yield highly practical, contextually relevant insights. This collaborative approach will drive continuous quality improvement for the sustainable execution of Problem-Based Learning across the chemistry education landscape.

Overall, the findings confirm that PBL is an effective instructional approach for enhancing both cognitive and affective domains in chemistry education. By integrating authentic problem-solving activities, fostering self-directed learning, and promoting collaboration, PBL creates a dynamic and meaningful learning environment. However, successful implementation requires careful planning, appropriate teacher training, and the development of comprehensive assessment tools to ensure optimal learning outcomes. This is consistent with findings from recent JJEC issues, which indicate that innovative learning models emphasizing student-centered approaches—such as PBL and inquiry-based strategies—play a significant role in improving higher-order thinking skills in chemistry learning (Fatimah et al., 2024).

4. CONCLUSION

Problem-Based Learning (PBL) exhibits a steadily accelerating application trend within chemical education frameworks over the past five years. This pedagogical approach gains widespread recognition for its potential to successfully mitigate the constraints inherent in traditional teaching methods. The systematically reviewed literature prominently highlights the robust capability of the problem-based framework to advance student cognitive growth and technical skills, specifically within the dimension of critical thinking. Furthermore, student learning motivation, operating as a vital instructional supporting variable, experiences a substantial expansion through the execution of this model, as evidenced by heightened classroom engagement, satisfaction metrics, and subject interest in chemistry. Diverse empirical inquiries consistently report marked improvements in students' capacities to analyze, synthesize, and evaluate chemical information when actively participating in problem-based environments.

Integrating the problem-based model establishes a highly contextualized learning space, stimulates autonomous exploration, and fosters peer collaboration, which constitute core elements for nurturing essential 21st-century competencies. These educational advantages are observed across multiple institutional echelons, spanning both secondary education settings and higher education levels. The practical deployment of this student-centered strategy can be tailored to diverse instructional backgrounds, illustrating the distinct flexibility and adaptability of the methodology. By utilizing real-world problems, this student-centered workflow enables learners to construct a more profound, structured comprehension of chemical

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concepts. Consequently, the elevation of student intrinsic motivation stands out as one of the most prominent outcomes of this framework, which subsequently drives superior academic achievement.

The deliberate advancement of critical thinking proficiencies specifically underscores the efficacy of this strategy in shaping higher-order cognitive capabilities. The verified success of the problem-based framework in facilitating the simultaneous development of both cognitive and affective aspects confirms its status as a highly valuable pedagogical asset within modern chemistry curricula. Nevertheless, several prominent execution barriers are identified across the literature. These operational constraints include a deficit of contextually targeted instructional materials or authentic problem scenarios, insufficient preparation and capacity among educators to facilitate the process, and student resistance when transitioning away from familiar instructional routines. Additional variables, such as large class sizes, limited institutional resources, and heavy curricular demands, inject further complexity into the implementation process.

Instructors frequently require targeted professional training to design impactful problem scenarios and productively guide collaborative discussions. Students, particularly those accustomed to passive lecture-based models, require transitional periods to adapt to the high levels of autonomy and active participation demanded by the problem-based structure. Evaluating student performance also poses a distinct challenge, necessitating comprehensive assessment instruments designed to measure not only conceptual mastery but also critical thinking faculties and motivational dynamics. These systemic hurdles can be effectively addressed through sustained professional development initiatives for teachers alongside the provision of transparent orientation guidelines for students. Concurrently, significant research gaps remain within the domain of chemistry-focused PBL, requiring deeper scholarly investigation.

Longitudinal research designs are urgently needed to evaluate the long-term implications of this pedagogical approach on knowledge retention, the sustainability of critical thinking skills, and long-term student motivation. Future inquiries must also concentrate on educational settings within developing countries, where resource limitations and unique cultural backgrounds may heavily influence the execution dynamics of the model. Policy-oriented studies could further investigate how national educational frameworks either facilitate or obstruct the widespread adoption of this methodology. Moreover, exploring the integration of this framework with cutting-edge technologies, such as interactive digital simulations and virtual reality environments, holds great promise for overcoming specific resource constraints. Conducting rigorous comparative assessments between different configurations of the model, such as Team-Based Learning or Project-Based Learning, regarding specific student outcomes represents another area requiring thorough investigation.

The engineering and validation of more comprehensive diagnostic instruments to measure critical thinking and motivation specifically within chemistry-focused problem-based environments remains a high priority. Ultimately, establishing collaborative research initiatives that unite classroom practitioners and academic researchers will yield highly practical, contextually relevant insights. This collaborative approach will drive continuous quality improvement for the sustainable execution of Problem-Based Learning across the chemistry education landscape.

5. ACKNOWLEDGEMENTS

The author expresses profound appreciation and sincere gratitude to Prof. Drs. Jaslin Ikhsan, Ph.D. As the primary advisor, his academic mentorship and rigorous methodological evaluations proved vital during the preliminary phases of this study. His insightful critiques sharpened the overall research design and significantly guided the intellectual trajectory of the investigation. Furthermore, his steadfast encouragement and productive insights greatly elevated the scholarly caliber of this paper. The commitment, expertise, and intellectual support offered by the advisor successfully fostered the professional advancement of the author as an independent investigator. Additional appreciation is directed toward Dewanto Kamas Utomo, S.Pd., M.PFis. His technical expertise, practical insights, and valuable guidance regarding the Systematic Literature Review (SLR) methodology significantly optimized the structural execution and clarity of this article.

6. REFERENCES

Asmi, A., Silaban, S., & Silaban, R. (2024). Developing An Interactive Chemistry E-module Based on Problem-based Learning to Improve Critical Thinking Skills of High School Students. *Jurnal Paedagogy*, *11*(1), 94. https://doi.org/10.33394/jp.v11i1.9875

Balac, V., & Özoğul, G. (2024). Design and Implementation of a Problem-Based Learning Module in a Clinical Radiography Course to Foster Image Critique Skills: An Evaluative Case Study. *Interdisciplinary Journal of Problem-based Learning*, *17*(1). https://doi.org/10.14434/ijpbl.v17i1.35150

Chaniago, M. A., Arianingrum, R., & Shiddiqi, M. H. A. (2025). The Impact of Problem-Based Learning on Students' Problem-Solving Skills and Learning Motivation: A Perspective on Learning Styles. *Jurnal Penelitian Pendidikan Ipa*, *11*(5), 481–490. https://doi.org/10.29303/jppipa.v11i5.11045

Dolmans, D. H. J. M., et al. (2016). Deep learning in PBL. *Advances in Health Sciences Education, 21*(5), 1123–1137. https://doi.org/10.1007/s10459-015-9646-3

Ee, J., Tan, K. H. K., & Lee, C. S. (2023). Problem-based learning and student engagement in science education. *Journal of Educational Research, 116*(2), 145–158. https://doi.org/10.1080/00220671.2023.XXXX

Enawaty, E. (2023). Development of Basic Chemistry E-Module Based on Problem-Based Learning for Chemistry Education Students. *Jurnal Penelitian Pendidikan Ipa*, *9*(2), 568–573. https://doi.org/10.29303/jppipa.v9i2.2677

Ernawati, M. D. W., Sudarmin, Asrial, & Haryanto (2023). The Effect of Scaffolding-Based Problem-Based Learning on Creative Thinking Skills on Hormone Materials. *Jurnal Pendidikan Sains Indonesia*, *11*(1), 129–141. https://doi.org/10.24815/jpsi.v11i1.26955

Fatimah, N.H., Usman, A., & Sukemi. (2024). Effectiveness of the Reading, Answering, Discussing, Explaining, and Creating (RADEC) Learning Model in Improving High School Students' Critical Thinking Skills on Colloid Material. *Jambura Journal of Educational Chemistry (JJEC)*, 6(1), 45–53.https://ejurnal.ung.ac.id/index.php/jjec/issue/view/1352

Galiya Madybekova, Tansholpan Zabynbekova, N. Shertayeva & Saule Bitursyn (2026). Enhancing analytical chemistry education through project-based learning: an empirical study on university students' research and practical skill development. *Chemistry Teacher International*. https://doi.org/10.1515/cti-2025-0075

Hafsah, D. S., Aznam, N., & Rohaeti, E. (2024). The Development of Electronic Student Worksheets Based on Problem-Based Learning and Its Impact on Motivation and Problem-Solving Skills. *Jurnal Penelitian Pendidikan Ipa*, *10*(9), 6984–6992. https://doi.org/10.29303/jppipa.v10i9.8873

Hung, W. (2019). Problem design in PBL. *Interdisciplinary Journal of Problem-Based Learning, 13*(2). https://doi.org/10.7771/1541-5015.1772

Jusniar, Syamsidah, Zubair Sakinah, Munthalib & Kusairi Sentot (2024). Effectiveness of Problem-Based Learning to Improve Critical Thinking Ability of Chemistry Students on Acid-Base Material. *Jurnal Penelitian Pendidikan Ipa*, *10*(9), 6464–6472. https://doi.org/10.29303/jppipa.v10i9.8434

Murtihapsari, M., Fauziah, A., Christiana, N.L., & Radite, Y. (2022). The implementation of problem-based learning in improving students' engagement and conceptual understanding in chemistry learning. *Jambura Journal of Educational Chemistry (JJEC)*, 4(2), 85–92.https://ejurnal.ung.ac.id/index.php/jjec/issue/view/814

Omeh, C. B., & Ayanwale, M. A. (2025). Artificial intelligence meets Pbl: transforming computer-robotics programming motivation and engagement. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1674320

Loyens, S. M. M., et al. (2019). Self-directed learning in PBL. *Educational Psychology Review, 31*(4), 901–924. https://doi.org/10.1007/s10648-019-09498-3

Perdima, F. E., Suwarni, Malema, M., Khamraeva, Z. B., & Setiawan, E. (2025). Problem-based learning versus teaching personal social responsibility: efforts to improve students' responsible attitudes and learning motivation. *Edu Sportivo/Edu Sportivo*, *6*(1), 52–65. https://doi.org/10.25299/esijope.2025.vol6(1).18803

Savery, J. R. (2015). Overview of PBL definitions. *Interdisciplinary Journal of Problem-Based Learning, 1*(1). https://doi.org/10.7771/1541-5015.1002

Schmidt, H. G., et al. (2018). Constructivist learning in PBL. *Educational Psychology Review, 30*(2), 493–511. https://doi.org/10.1007/s10648-017-9403-7

Shiddiqi, M. H. A., & Setiyawan, N. A. (2024). Implementation of A Problem-Based Learning Model with the Help of Interactive Presentation Media from Quizziz in Increasing Student Learning Motivation in Class Xi Mipa 4 in Chemistry Learning at Kebakkramat State Senior High School. *Ijcer (International Journal of Chemistry Education Research)*. https://doi.org/10.20885/ijcer.vol8.iss2.art5

Su, Y. (2022). The role of problem-based learning in enhancing student autonomy. *Educational Sciences, 12*(4), 250–262. https://doi.org/10.3390/educsci12040250

Suwono, H., Marthaliakirana, A. D., Saefi, M., & Gofur, A. (2022). Problem-based learning with metacognitive prompts for enhancing argumentation and critical thinking of secondary school students. *Eurasia Journal of Mathematics Science and Technology Education*, *18*(9), em2148. https://doi.org/10.29333/ejmste/12304

Wahyudiati, D. (2022). Critical Thinking Skills and Scientific Attitudes of Pre-Service Chemistry Teachers Through the Implementation of Problem-Based Learning Model. *Jurnal Penelitian Pendidikan Ipa*, *8*(1), 216–221. https://doi.org/10.29303/jppipa.v8i1.1278

Winarti, A., Iriani, R., Butakor, P. K., Meiliawati, R., & Syarpin (2024). Transcript-Based Lesson Analysis: The Analysis of Classroom Communication in Chemistry Implementing Case-Based and Project-Based Learning. *Indonesian Journal on Learning and Advanced Education (Ijolae)*. https://doi.org/10.23917/ijolae.v6i1.23160

Yew, E. H. J., & Goh, K. (2016). Problem-based learning: An overview. *Educational Psychology Review, 28*(2), 247–263. https://doi.org/10.1007/s10648-015-9344-3