Journal of Mathematics Science and Computer Education
https://ppjp.ulm.ac.id/journals/index.php/jmsc-edu/index
e-ISSN: 2807-9167 p-ISSN: 2807-9329
Vol 5 No 1 2025
DOI: https://doi.org/10.20527/jmscedu.v5i1.14779

Literature Review: Application of the Problem-Based Learning (PBL) Model to Critical Thinking Skills in Chemistry Learning Materials

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Article Info

Article history:
Received: February 2, 2025
Accepted: May 26, 2025
Published: June 8, 2025

Keywords:
Chemistry learning materials
Critical thinking skills
Literature review
PBL

Abstract

Critical thinking is analyzing, evaluating, and synthesizing information logically and objectively to make informed decisions. The low critical thinking ability in chemistry learning can be attributed to the lack of application of knowledge that emphasizes problem-solving, the prevalence of rote memorization methods, and the limited use of approaches that encourage exploration and analytical thinking. This research investigates the effect of implementing the Problem-Based Learning (PBL) model on developing critical thinking skills in chemistry education. The research method used is the Systematic Literature Review (SLR) method. Research data were obtained from reputable journal articles collected using Harzing's Publish or Perish 8 application, selected from journals published within the last 5 years. Data is analysed in a qualitative descriptive manner by describing and interpreting the findings obtained. The literature review results indicate that PBL significantly enhances students' active involvement, facilitates collaborative learning, and effectively integrates theory with practice. Additionally, PBL has proven effective in developing analytical, evaluative, reflective, and creative skills in problem-solving. This research confirms that applying PBL in chemistry learning can positively impact students' critical thinking skills, improving the quality of chemistry education. Therefore, integrating PBL into the chemistry curriculum is highly recommended to prepare students to face real challenges with strong critical thinking skills.

To cite this article: Rusmansyah, R., Yanti, H., Saadi, P., Mahdian, M., Rusmanayanti, A., & Kusuma, A. E. (2025). Literature review: Application of the problem-based learning (pbl) model to critical thinking skills in chemistry learning materials. *Journal of Mathematics, Science, and Computer Eductaion, 5*(1), 43-56.

INTRODUCTION

Education in the 21st century is crucial for enhancing human resources and improving education (González-Pérez & Ramírez-Montoya, 2022; Hermawan & Arifin, 2021; Mufidah et al., 2021). These skills are essential for navigating challenges in an increasingly complex and uncertain world and achieving success in both personal and professional life.

These skills are not innate but acquired through practice, learning, or experience. Preparing human resources personnel with 21st-century skills will be effective if pursued through education (Malik, 2018; Redhana, 2019; Rios et al., 2020).

Teachers and students must be able to adapt to technological advances by preparing the education system and adjusting the competencies of teachers and students. The educational process must contribute to social life by producing productive, innovative, and creative outputs (Mufidah et al., 2021). Various educational reform efforts continue to be made by the government to improve the quality of education, including implementing an independent learning curriculum.

The independent learning curriculum is designed to produce students who excel in various aspects, such as independence, courage, politeness, and competence (Hasim, 2020). Learning is designed to provide more freedom and flexibility, and it is very relevant and practical in facing the challenges of 21st-century learning. In an era where critical thinking skills, creativity, collaboration, and digital literacy are crucial, the independent curriculum encourages students to develop these competencies through a student-centered learning approach. It allows educators to customize teaching methods according to the needs and potential of learners, thus facilitating more personalized and meaningful learning (Redhana, 2019). Additionally, integrating technology into the learning process enhances students' mastery of essential digital skills. Thus, its implementation prepares students to face future challenges and equips them with the ability to become adaptive and innovative lifelong learners (Pamungkas et al., 2020).

21st-century learning demands developing skills beyond academic knowledge, including critical thinking, creativity, collaboration, and digital literacy. To support the development of these skills, an appropriate and effective learning model is needed, one of which is Problem-Based Learning (PBL) (Hmelo-Silver, 2004). The approach employed is an innovative learning method that focuses on problem-solving as the primary means of learning new concepts (Ceker & Ozdamli, 2016; Nurkhin & Pramusinto, 2020; Zubair & Yanto, 2022).

Since its introduction at McMaster University's Faculty of Medicine in the 1960s, various disciplines in Canada have adopted this learning model due to its effectiveness in improving students' critical thinking and problem-solving skills (Hayati et al., 2023). This model emphasizes that students are at the center of learning by using real-world problems to develop critical thinking skills, problem-solving abilities, and new knowledge. Students' critical thinking skills will improve through interactive learning, where students act as active thinkers. Educators act as mediators, facilitators, and motivators, helping students achieve their goals. This model aims to demonstrate its impact on students' critical thinking skills and guide lecturers and educators in designing learning that supports this (Jamilah et al., 2023) Misbah et al., 2022; Yani et al., 2021).

Critical thinking skills are essential in education, particularly in science fields such as chemistry. These skills include analyzing, evaluating, and creating solutions based on available information (Arviani et al., 2023; Haryandi et al., 2019; Misbah et al., 2024). However, various studies indicate that students' critical thinking skills in Indonesia remain relatively low. Students still have difficulties understanding basic concepts about science, especially in terms of interpretation and application in chemistry. Additionally, scientific theories and laws can be challenging for students to comprehend (Wayudi et al., 2020).

This is evident in various studies demonstrating that students often struggle with critical thinking. Several factors cause this low skill, including: (1) Traditional teaching methods, which tend to be one-way, where the teacher is the center of information, and students only receive without much interaction or reflection; there is not much room for students to develop critical thinking skills (Novitasari & Aznam, 2023). (2) Lack of practice in

problem-solving: Students are rarely given tasks that challenge them to solve problems independently or in groups. Most tasks given are memorization tasks that do not stimulate analytical skills (Laeli & Kasmui, 2024). (3) A non-conducive learning environment, including a lack of laboratory facilities and learning resources, is also an obstacle to developing critical thinking skills (Omar & Awang, 2023).

Critical thinking skills enable students to comprehend and apply complex concepts in practical scenarios or real-life situations (Suwahono & Zulfirman, 2023). These skills enable students to analyze data, evaluate arguments, and make evidence-based decisions. Thus, integrating PBL into chemistry learning can improve students' critical thinking skills (Islawati et al., 2024).

Although numerous studies have been conducted on the effectiveness of PBL in various fields of study, the literature still lacks specific research addressing the application of PBL in chemistry learning and its impact on students' critical thinking skills. Therefore, this literature review aims to explore and analyze existing research on the application of PBL in the context of chemistry learning and its impact on students' critical thinking skills. Data were reviewed based on reputable national and international journals.

METHODS

This research employs the literature review method to examine the application of the PBL model to developing critical thinking skills in chemistry learning. The literature study was chosen as a methodology because it allows researchers to collect, analyze, and synthesize relevant and reliable studies from published sources.

A literature review collects data or sources related to a particular topic from various sources, such as journals, books, the internet, and other literature, including literature analysis from Google Scholar and Scopus.com (Darwin et al., 2024). The data collection method is shown in Figure 1.

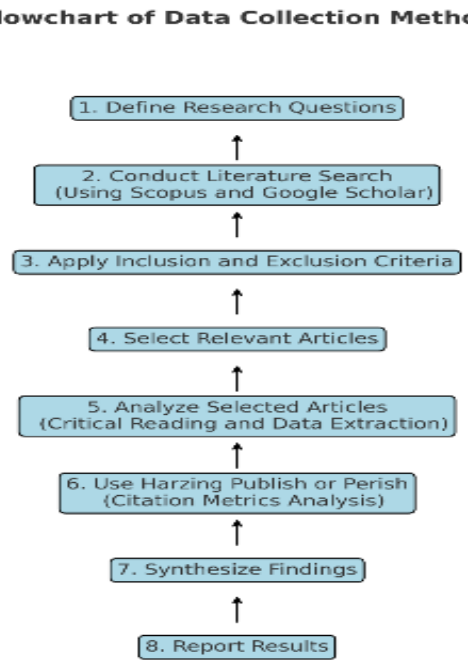

Figure 1 Data collection method

The first step in this methodology is to identify and collect journal articles, books, and other academic sources that discuss PBL and critical thinking skills in the context of chemistry learning. To ensure relevance and currency, these sources were retrieved from reputable journal databases using Harzing's Publish or Perish 8 application, with a publication deadline of the last five years.

Inclusion criteria for literature selection included (1) Relevance to the research topic, (2) Quality of sources, and (3) Period of publication. The data analysis process was conducted using the content analysis method, where each article was evaluated to identify key findings related to PBL implementation and its impact on critical thinking skills. Data were categorised based on key variables, including the PBL method, types of critical thinking skills measured, research results, and learning context. The last step is synthesizing the findings from various studies to provide a comprehensive picture of how PBL affects students' critical thinking skills in chemistry learning. This literature study approach is expected to significantly contribute to understanding and developing effective learning strategies that improve students' critical thinking skills through the PBL model in chemistry education.

RESULTS AND DISCUSSION

The selection of national journal research relevant to applying the PBL model to critical thinking skills in chemistry learning materials resulted in 13 national and two international journals. The selected journals are listed in Table 1.

Table 1 Results of the literature review on applying the problem-based learning model to chemistry education

Authors	Journal Name (Index)	Method	Research Result
Islawati et al. (2024)	VENN: Journal of Sustainable Innovation on Education, Mathematics and Natural Sciences (Nasional)	Literatur review	PBL effectively improves students' critical thinking skills and prepares them to face complex challenges in the real world.
Zahro dan Lutfianasari (2024)	Jurnal Inovasi Pendidikan Kimia (Sinta 3)	Quantitative research: quasi-experimental design using the nonequivalent control group design method	Applying the PBL learning model is effective because it can enhance students' critical thinking skills and learning outcomes related to salt hydrolysis.
Amora et al. (2024)	UNESA Journal of Chemical Education (Sinta 4)	Collaborative Classroom Action Research	The PBL model, when combined with the contextual concept of Ethnochemistry, can train students' critical thinking skills.
Asmi et al. (2024)	Journal Paedagogy: Jurnal Penelitian dan Pengembangan Pendidikan (Sinta 3)	ADDIE (Analysis, Design, Development, Implementation, Evaluation).	The designed e-module successfully improved students' critical thinking skills, as evidenced by an increase in the N score to 0.48, which falls within the moderate category. The average score of students' critical thinking skills when using the e-module increased by 55%, which fell into the critical category.

Saputri dan Suprihatiningrum (2023)	UNESA Journal of Chemical Education (Sinta 4)	Qualitative literature review and descriptive analysis	This study demonstrates that the learning methodology significantly influences critical thinking skills and the application of green chemistry to acid-base materials. PBL is a highly effective learning strategy.
Gazali and Dasna (2023)	Edukatif: Jurnal Ilmu Pendidikan (Sinta 4)	Systematic review	The dominant learning models studied to enhance critical thinking skills are PBL and inquiry-based learning models.
Sulastry et al. (2023)	Jurnal Pendidikan Sains Indonesia (Sinta 2)	The one-group pretest-posttest design	Learning using the PBL model is effective for students' learning outcomes in class XI IPA 1 SMA Negeri 8 Pinrang, particularly in the context of acid-base material, with an average of 0.75, which falls in the high category.
Yu and Zin (2023)	Frontiers in Education (Q2)	Systematic review	PBL adaptations that effectively develop critical thinking skills improve students' critical thinking abilities. This can happen because adaptations made to the PBL model, such as the use of rubrics, video-based cases, or problem-solving-oriented approaches, enable students to become more skilled in identifying problems, formulating solutions, and communicating scientifically about the results of their problem-solving.
Jamilah et al. (2023)	IJLECR (Sinta 3)	Quasi-eksperimen	Applying the PBL model positively impacts improving students' critical thinking skills.
Khairunnisa et al. (2022)	QUANTUM: Jurnal Inovasi Pendidikan Sains (Sinta 3)	Pre-experiment: one-group pretest-posttest design	The results showed that implementing the STEM-based PBL model with virtual reality media can improve students' critical thinking skills and self-regulation.
Zubair and Yanto (2022)	ChemEdu (Jurnal Ilmiah Pendidikan Kimia)	Literature study	A learning model emphasizing students' activity can help students foster critical thinking skills in chemistry.
Wahyudiati (2022)	Jurnal Penelitian Pendidikan IPA (Sinta 2)	Quasi-eksperimen	Applying the PBL model positively impacts chemistry teacher candidates' critical thinking skills and scientific attitudes. This shows that the learning model improves students' critical thinking skills and scientific attitudes in the Basic Chemistry 1 course.
Ramandha and Indriani (2021)	Jurnal Pendidikan dan Pembelajaran Kimia (Sinta 4)	Metode quasi-eksperimen	Students taught using the PBL model have better critical thinking skills than those taught using the guided inquiry learning model.

Miterianifa et al. (2020)	Journal of Physics: Conference Series (Q4)	Literature study	The PBL model can potentially enhance students' critical thinking skills by enabling them to apply problem-solving concepts in everyday life. Encouraging students' abilities, especially critical thinking, will impact learning outcomes.
Suyanta (2020)	Jurnal Ideguru (Sinta 3)	Classroom Action Research	The PBL Learning Model in Chemistry Subjects can improve students' critical thinking skills with the results of observations of critical thinking skills in cycle I by 57.58% and cycle II by 78.79% and the results of critical thinking skills tests in cycle I by 45.45%, cycle II by 87.88%.

The application of the PBL model to critical thinking skills in chemistry learning materials based on the year of publication is shown in Table 2.

Table 2 Year of article publication

No	Year of Article Publication	F	Percentage
1	2020	2	13%
2	2021	1	7%
3	2022	3	20%
4	2023	5	33%
5	2024	4	27%
Total		**15**	**100 %**

Research using the PBL model in chemistry education has consistently shown positive results in improving students' critical thinking skills. PBL is a learning approach based on solving real-world problems relevant to the subject matter. This approach helps students understand chemistry concepts and develop the analysis, evaluation, and synthesis skills essential to critical thinking.

Research by Islawati et al. (2024) comprehensively describes the benefits of implementing PBL in enhancing students' critical thinking skills, particularly in chemistry education. The research demonstrates that PBL effectively enhances students' analysis, evaluation, interpretation, and reflection skills, resulting in significant improvement. Additionally, PBL offers benefits in terms of real-world relevance, allowing students to apply their knowledge in everyday life. Results from longitudinal studies also indicate that the positive benefits of PBL persist long-term, with consistent improvements in students' critical thinking skills observed one year after PBL implementation. Therefore, it is recommended that PBL be implemented in the curriculum as a highly recommended strategy to develop students' critical thinking skills and improve the quality of learning.

Research conducted by Zahro and Lutfianasari (2024) on applying PBL models to salt hydrolysis material identified several advantages and disadvantages. One of the advantages that can be concluded from this research is the effectiveness of PBL in improving students' critical thinking skills and learning activities, which aligns with the theory of constructivism, which emphasizes learner-centered learning to achieve higher levels of thinking.

Applying PBL to salt hydrolysis material significantly impacts critical thinking skills and learning activities. Research shows that PBL makes learners more active, develops critical thinking skills, and helps them better understand complex concepts such as salt

hydrolysis. In addition, it encourages learners to identify problems, formulate hypotheses, collect data, analyze information, and find answers to the issues given, thus gaining a deeper understanding of problem-solving and making learning more meaningful and effective. Using the PBL model, this learning activity trains students in critical thinking about problems assigned by the teacher.

This model not only positively impacts critical thinking skills and learning activities but also enhances collaborative skills, problem-solving abilities, and the application of concepts in real-world contexts. Through the PBL approach, learners become active participants in the learning process. They can learn the material and its content more deeply, experience deeper learning, and develop important metacognitive skills. In addition, this model also encourages learners to connect theory and practice, deepen their understanding through discussion and reflection, and increase learning motivation and interest in the subject matter. However, one of the drawbacks of this model is that the learning design requires a significant amount of time, and learners are expected to be actively involved in the learning process, necessitating educators to dedicate a substantial amount of time and energy.

Thus, although the PBL model effectively improves students' critical thinking skills and learning activities, educators must consider the preparation and time needed to implement this model optimally. Teachers must devise the right strategy for preparing and implementing this PBL model to ensure that the learning process does not exceed the time allocated in the curriculum. Teachers can share different problems among groups and present them in turn, allowing students to gather information about the material studied by the group. If solving the problem takes a long time, the teacher can assign tasks in advance to the group of students, both in the laboratory and at home, so that when in class, the group can present a report. Thus, learning can be achieved on time.

Researchers chose the PBL learning model for this study on colloidal materials because it effectively develops students' critical thinking skills. The PBL model provides students with authentic and meaningful problem situations that stimulate them to think critically, analyze information, and find solutions independently. By integrating the contextualized concept of ethnochemistry, PBL can effectively relate colloidal materials to learners' everyday lives or environments. This makes learning more relevant and engaging for the students, making it easier for them to understand the concepts taught. Several supporting factors strengthen the application of the PBL model in reinforcing colloidal materials, including authentic problem situations, developing critical thinking skills, contextual integration of ethnochemistry, and improving student learning outcomes. With these supporting factors, the PBL learning model is ideal for training students' critical thinking skills and making colloidal learning more contextual and relevant.

The PBL model positively impacts the learning process (1). Increasing students' active participation: PBL encourages students to actively participate in the learning process through group discussions, independent research, and presentation of their findings. A study by Rizki and Suprapto (2024) found that students who learn through PBL are more likely to ask questions and engage in discussions, which are important indicators of critical thinking. (2) Facilitate collaborative learning: One of the benefits of PBL is its ability to promote collaborative learning. Students learn to work in groups to solve complex problems, improving communication and collaboration skills. According to research published in the International Journal of Scientific Research and Management, students who engaged in PBL demonstrated an improved ability to work in teams and solve problems collaboratively (Kamanga & Shumba, 2022). (3) Integration of theory and practice: PBL enables students to apply chemistry theory practically. This improves conceptual understanding and makes learning more relevant and interesting. Tian et al.

(2023) showed that students who learned through PBL could better relate chemical concepts to real-life situations, strengthening their understanding and retention.

PBL has increased critical thinking skills: (1) Development of analysis skills: PBL requires students to analyze problems in depth before coming up with solutions. This analysis involves identifying problems, gathering relevant information, and evaluating the data. Research conducted by Sartika et al. (2023) found that students who employed PBL demonstrated significant improvement in analytical skills compared to traditional learning methods. (2) Evaluation and reflection: Students in PBL are encouraged to continually evaluate the solutions they develop and reflect on their learning process. According to a study by Wahdaniyah et al. (2023), this reflective ability enables students to identify the strengths and weaknesses of their arguments, a crucial component of critical thinking. (3) Creativity in problem-solving: PBL encourages students to think creatively to solve complex problems. This process involves brainstorming, thinking creatively, and exploring new approaches. Research published in the Journal of Chemical Education Innovation shows that students engaged in PBL are more creative and innovative in solving chemical problems (Simangunsong, 2023).

CONCLUSION

Based on the analysis, this study concludes that the literature shows that the PBL model significantly improves students' critical thinking skills in chemistry. PBL makes learning more engaging and interactive, preparing students to face real-world challenges with strong analytical and reflective skills. Therefore, integrating PBL into the high school chemistry curriculum is highly recommended to improve the quality of learning and students' critical thinking skills.

CONFLICTS OF INTEREST

We declare that the articles created and published in this journal have no conflict of interest with any party.

AUTHOR CONTRIBUTIONS STATEMENT

R and HY: conceptual framework, research methods, data analysis; PS: script writing; M: data analysis and language of article manuscripts.

ACKNOWLEDGMENTS

The author would like to thank the Dean of FKIP ULM, the Chemistry Education Study Program of FKIP ULM, and the lecturers and teachers who provided support and assisted in completing the research so that they could compile this article.

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