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Problem-Based Learning Strategies to Improve Students' Science Literacy in Chemistry Subjects: A Recent Literature Review

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ABSTRACT

21st-century learning requires students to have adequate science literacy skills, especially in understanding complex and abstract chemistry materials. However, the results of international assessments show that students' science literacy skills, including in Indonesia, are still not optimal. This study aims to analyze the application of the Problem-Based Learning (PBL) model in improving science literacy in chemistry learning at the high school (SMA/MA) level. The method used is a Systematic Literature Review (SLR) by analyzing articles published between 2018 and 2024. Based on the results of the analysis, 13 articles were obtained that met the inclusion criteria. The results of the review show that the application of PBL consistently strengthens the understanding of science concepts in depth and improves students' critical thinking and problem-solving skills. This learning model not only supports academic achievement but also helps students relate the knowledge learned to real situations, thereby improving the quality of science literacy needed in today's chemistry learning.

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INTRODUCTION

One of the challenges of learning in the 21st century is to develop students with adequate science literacy skills (Suryani & Rusmini, 2022). Learning in the 21st era emphasizes Model 6C skills, namely, Critical Thinking (critical thinking skills), Creativity (Creativity in problem solving), Collaboration (the ability to work together), Communication (effective communication skills), Culture/Citizenship (cultural understanding and civic responsibility), and Character Education/Connectivity (character formation and ability to connect in a global network) designed to equip students with holistic abilities in dealing with the complexities of modern life (Susandi et al., 2025).

Among these various competencies, science literacy occupies a central position in learning. Science literacy functions as a bridge between theoretical understanding of science and its application in the context of the real world (Cahyo & Diyana, 2025). Literacy is defined as a person's ability to apply scientific understanding to recognize issues or phenomena and to critically evaluate data-based information using accountable critical thinking skills (S. Handayani, 2025a; Febria Utami & Bahri, 2025a). Science literacy is not only defined as memorizing scientific concepts but also includes a deep understanding of science principles in depth (Rina Hidayati Pratiwi et al., 2025; Khotimah, 2020).

However, the science literacy ability of students, as measured by PISA (Program for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) in various countries, including Indonesia, has still not reached a satisfactory level (S. A. Handayani, 2025; S. Handayani, 2025b). In fact, in Indonesia, science literacy is prioritized as a fundamental competency that every student must possess (Febriana et al., 2024). The Independent Curriculum makes it a central part of the students' learning process (Balqis et al., 2025). Currently, educational innovation is focused on character building, developing students' potential, and flexible and contextual learning according to the needs of the 21st century (Febriyanti & Siregar, 2025). However, in practice, the implementation of these principles still faces challenges, especially in conceptual and abstract subjects such as chemistry (Adminira Ruslan et al., 2024).

Chemistry subjects at the high school level are often considered difficult for students to learn and understand (Ardila & Sudrajat, 2023; Aziz et al., 2024). Many students consider chemistry to consist of complex, abstract concepts that require multi-level representation (Alvina et al., 2024; Ardila et al., 2025). Chemistry teachers are required to be more creative and persistent in teaching difficult concepts, enabling students to understand chemistry material (R. Febriyanti & Widjajanti, 2023).

Among all the chemistry materials in high school, several learning topics are often cognitive obstacles for students, namely the concepts of acids and bases, atomic structure, periodic systems of Elements, Chemical Bonds, and Buffer Solutions. This material not only demands an understanding of macroscopic phenomena (Kurniawati et al., 2023) (Karina & Amelia, 2025). However, it also requires the ability to represent and model microscopic processes, such as the ionization of solutes and interactions between particles at the molecular level. In addition, mathematical calculation materials, such as those used in Thermochemistry, are also a challenge for students because students need mastery of formulas, numerical logic, and quantitative analysis skills (Yuhelman et al., 2025; Oktaria & Purba, 2024)

Science literacy skills during learning activities can be optimized by applying learning methods that actively involve students in the scientific process. There are several effective learning models to improve science literacy in 21st-century education. One of them is problem-based learning (PBL), which can enhance scientific thinking (Raysiffa Wulandari et al., 2025; Pratama, 2025) and can be applied by students as active participants to address various real problems in community life during the learning process (Pratama, 2025) (Wahyudin, 2023). This strategy is one of the efforts to develop science literacy skills needed in the 21st century (Hapsari et al., 2023).

The PBL model is an approach designed to actively involve students in solving real problems through the process of thinking, discussing, and understanding the material in depth (Hidayatullah & Fahmi, 2025; Erayani & I Nyoman Jampel, 2022). The application of the PBL learning model opens up great opportunities for students to hone their critical thinking skills and science skills (Saputra et al., 2023) (Febria Utami & Bahri, 2025b) as well as formulate solutions and communicate the results scientifically (Yulianti et al., 2025) (Yanti et al., 2024). Student involvement in the implementation of PBL syntax can significantly improve literacy skills and enhance active communication and collaboration in groups (Afrianti et al., 2025; Sugiarti et al., 2025). However, studies that provide a comprehensive insight into the application of PBL in building students' science literacy, especially considering certain time periods and the most frequently focused topics in PBL research, are still limited. Therefore, this research was conducted to analyze the latest studies and strengthen the empirical foundation for applying PBL in chemistry learning.

METHOD

This research is qualitative, using the Systematic Literature Review (SLR) approach. This method is applied systematically to identify, evaluate, and synthesize relevant current scientific publications. The SLR method includes five main steps: formulating research questions, creating search strategies, establishing inclusion and exclusion criteria, analyzing data, and reporting results (N. M. Putri et al., 2024; Murti et al., 2024). The stages of data collection are as follows:

1. The first stage is to formulate the following questions: 1. How many articles that discuss the application of PBL to chemical materials to improve science literacy skills have been published? 2.) What chemicals are most widely applied? 3.) What is the impact of the application of the Problem-Based Learning (PBL) model on the development of science literacy of high school (SMA)/MA students?
2. The second stage is to determine the data search strategy: The data search is carried out on the Google Scholar (https://scholar.google.com) website with a publication time limit between 2018 and 2024.
3. Third Stage, Establish Inclusion Criteria: Articles included in the review must meet the following inclusion criteria: (1) published in SINTA-indexed scientific journals; (2) contain quantitative, qualitative, or mixed data that explicitly examines the implementation of the Problem-Based Learning (PBL) model in the context of chemistry learning in SMA/MA to improve science literacy; (3) journal articles are available in full paper and can be accessed openly; (4) The search was conducted using the keywords: "problem-based learning", "science literacy ability", and "high school chemistry lessons". Articles that do not meet these criteria will be excluded from the analysis.
4. Fourth stage, analyzing data: The data obtained is synthesized to analyze and evaluate the research results in accordance with the research topic, namely: Problem-Based Learning to Improve Students' Science Literacy in Chemistry Subjects.
5. Fifth stage, reporting results: At this stage, the writing of the results and the discussion, and drawing of conclusions related to the findings.

The entire Systematic Literature Review (SLR) process. Following a systematic flow based on the PRISMA guide (Habibi & Artha Glory Romey Manurung, 2023) starts from source identification, title, and abstract filtering, to full-text selection as seen in Figure 1.

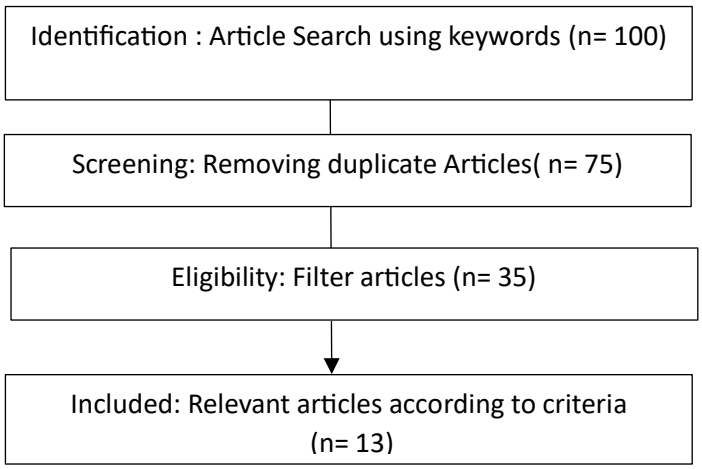

Figure 1. Article Search Process using the PRISMA method

RESULTS AND DISCUSSION

Based on the results of article data analysis using the PRISMA method, 100 articles were identified from the database, 25 of which were removed before the screening process (articles from journals that were not peer-reviewed). After 75 articles were initially identified, further screening based on eligibility criteria was conducted, resulting in 35 articles that qualified for further analysis. At the final stage, a thorough examination was conducted to select articles that were truly relevant and met the inclusion criteria, resulting in the selection of 13 articles. The results of the article analysis are described in Table 1.

Table 1. Article Analysis Results

No	Source (Author, Year)	Title	Material	Research Methods	Sample	Findings
1	(Asma dan, 2018)	The development of lkpd is oriented to the problem based learning (pbl) model to train science literacy skills in attitude aspects in reaction rate materials for students in grade xii of sma negeri 1 kedungwaru tulungagung	Reaction Rate	Quantitative	Class XII State High School 1 Kedungwaru Tulungagung	The PBL model integrated in the LKPD has succeeded in growing the attitude aspect in science literacy, with a classical completeness rate of 73.33%.
2	(Fauziah et al., 2019)	Improving Students' Science Literacy Through Green Chemistry-Oriented Problem-Based Learning on Reaction Rate Materials	Reaction Rate	Quantitative	Man 1 Mataram	There is an increase in science literacy with a moderate category in reaction rate materials applied by the PBL model
3	(Herdiawan et al., 2019)	Application of PBL to Improve Students' Creative	Colloid	Quantitative	IPA XI	There is an increase in students' science literacy using PBL with

		Thinking Skills on Colloidal Concepts				a medium category
4	(Desimah et al., 2019)	Application of Project Based Learning Model to Improve Chemical Science Literacy of Grade XI Students in Colloidal Subject Matter	Colloid	Quantitative	Class XI High School	There was an increase in science literacy mastery measured using n-gain, which was 0.59 from the pretest and posttest results.
5	(Marlina et al., 2021)	The Influence of Problem-Based Learning Models on Students' Science Literacy	Electrolyte and non-electrolyte solutions	Quantitative	X Mia Man 2 Model Mataram	The application of the problem-based learning model has a very good and significant effect on students' science literacy
6	(Dinda Nur Azizah et al., 2021)	The Effect of the Problem Based Learning Model in the Context of Socio Scientific Issues on Students' Science Literacy Ability in Acid-Base Materials	Acid-Base	Quantitative	State High School 28 Tangerang Regency	Students' science literacy ability in acid-base materials has increased due to the use of the PBL approach
7	(Sanova et al., 2021)	Ethnoscience Approach Through Problem Based Learning Model Towards	Buffer Solution	Quantitative	XI Mipa 2	There was a significant increase in students' science literacy skills in buffer solution materials after

		Chemical Literacy Ability of Buffer Solution Materials				the implementation of the problem based learning (PBL) model.
8	(Nurul Ilmi et al., 2023)	Problem Based Learning Model: Its Impact on Students' Science Literacy Skills in Acid-Base Materials	Acid-Base	Quantitative	XI Sman 1 Wundulako	The use of problem-based learning models is effective in improving the science literacy of high school students, especially in acid-base materials
9	(Tri et al., 2023)	The Effect of the Problem Based Learning Model on the Science Literacy Ability of Class Xi Mia Students of Angkasa Maros High School	Buffer Solution	Quantitative	XI Mia Angkasa Maros High School	There is a significant difference in science literacy ability with PBL and conventional models.
10	(Nikmatur Rohmaya et al., 2023)	The Effectiveness of E-Lkpd Chemistry for High School/MA with a Problem-Based Learning Model in the Context of Social Science Issues in Improving Students' Science Literacy	Petroleum and Hydrocarbons	Quantitative	XI Mipa 1 Buleleng	There was an increase in science literacy with classical completeness of students of more than 75% with the application of PBL
11			Acid-Base	Quantitative		

	(Fadhliana et al., 2024)	Problem-Based Learning (PBL) on the topic of acid-base: Improving Students' Literacy Skills			XI State High School 1 Dewantara	Learning using pbl has been proven to increase students' science literacy on acid-base materials
12	(Amri et al., 2024)	Application Of The Problem-Based Learning To Improve Scientific Literacy Skills Through Practicum Worksheet For Grade 11 Students Of Senior High School 1 Samalanga	Acid-Base	Mixed Methods.	XI State High School 1 Samalanga	The application of the PBL model in the acid-base practicum worksheet is effective in improving students' science literacy
13	(Yanti et al., 2024)	Development of Basic Chemistry Law E-Module with Fliphtml5 Assisted Problem-Based Learning Model to Improve Critical Thinking Skills and Science Literacy	Basic Laws of Chemistry	Mixed Methods	XI-I Driving School of High School N 5 Banjarmasin	The application of PBL is effective in increasing students' science literacy with a high category of 0.77

Based on an analysis of relevant articles from the 2018 to 2024 data search range, 13 articles were found to meet the inclusion criteria for the study. Of these, two articles used mixed research methods. Meanwhile, the other articles used quantitative research methods.

1. The number of articles that discuss the application of PBL to chemical materials to improve science literacy skills that have been published

The search results conducted via the Google Scholar website yielded 13 articles, which are summarised in Figure 1. The articles used were those that met the inclusion criteria, focusing on

the application of Problem-Based Learning (PBL) in chemistry to improve science literacy skills between 2018 and 2024.

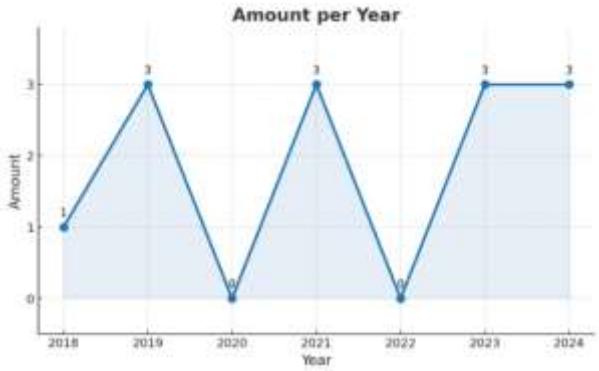

Figure 2. Number of Article Publications in 2020-2024

Figure 2 shows the number of articles that meet the inclusion criteria in the 2018–2024 period. There was 1 article in 2018, increased to 3 articles in 2019, then decreased to 0 articles in 2020. The number of publications rose to 3 articles in 2021, dropped to 0 in 2022, and then peaked with 3 articles in 2023 and 2024, respectively.

2. Chemical materials applied with PBL to science literacy skills

Based on the included articles, the materials most frequently used in studies on the application of Problem-Based Learning (PBL) to improve scientific literacy are illustrated in Figure 2. The highest frequency is found in the Acid-Base topic, followed by Reaction Rate, Colloid, and Buffer Solution. Meanwhile, Electrolyte and Non-Electrolyte Solutions, Petroleum and Hydrocarbons, and Basic Laws of Chemistry were less frequently represented.

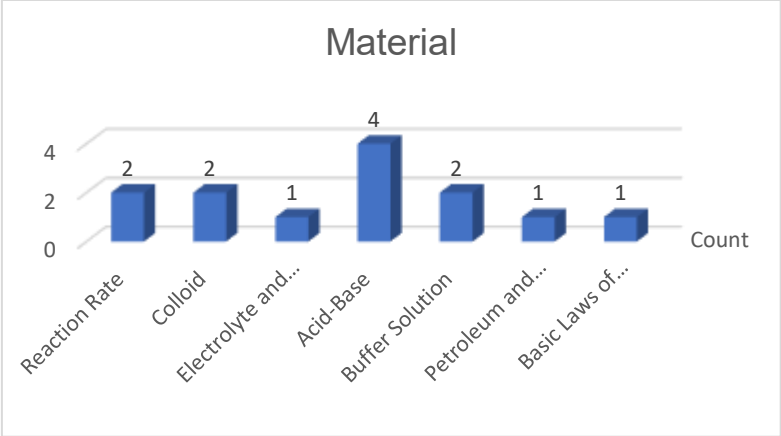

Figure 3. Distribution of Research Materials

Research on acid-base materials using the PBL model is the most widely found research. The PBL model is very helpful in improving understanding of scientific concepts and interpreting information. It evaluates evidence and applies scientific knowledge in daily life in depth through actively solving problems relevant to the learning material (Marselina et al., 2024) (Sari & Ahmad, 2025).

3. The impact of the application of the Problem-Based Learning (PBL) model on the development of science literacy of high school (SMA)/MA students.

Learning using the PBL model can improve students' science literacy skills because it focuses on real-life contexts (Inayah & Solihat, 2024). The application of problem-based learning positively influences the improvement of science literacy through PBL learning activities that train students to think critically (Hafiza & Nurhalisa, 2021).

Several studies that have applied PBL have also shown positive results related to improving science literacy skills (Andy Agustian & Sanusi, 2024). The results of the study (Yani et al., 2020) show that the use of the problem-based learning model helps students understand the concept of acid-base material in accordance with learning objectives. Research by A. J. H. Putri et al. (2025) shows a 63% increase in students' science literacy skills after being taught with the PBL model. Research conducted by Muliana et al. (2024) and Pujiyanti et al. (2025) also shows that learning strategies using the PBL model can provide opportunities for students to hone their scientific exploration and science literacy skills, which are not only beneficial for academics but also important for daily life.

PBL provides opportunities for students to hone their science literacy skills and critical thinking skills that involve the process of solving problems, and utilize scientific evidence through a series of learning stages, namely contextual problem identification, information search, hypothesis formulation, implementation of experiments or simulations, and drawing conclusions based on data (Mutmainnah et al., 2025). This stage of the process aligns with the aspect of science literacy, particularly in the ability to explain chemical phenomena scientifically.

CONCLUSIONS

A review of various articles discussing the improvement of science literacy in chemistry learning through the Problem-Based Learning (PBL) model found that PBL successfully strengthened the understanding of science concepts while developing students' critical thinking and problem-solving skills. This learning model positively impacts students' science literacy skills by connecting chemistry learning materials to daily life.

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