

PROBLEM-BASED LEARNING AS A STRATEGY FOR IMPROVING PROBLEM-SOLVING SKILLS IN SCIENCE LEARNING: A LITERATURE REVIEW

Karina Syahrul Hudda ^{*1)}, Laifa Rahmawati ²⁾

1,2) Master's Program in Science Education, Faculty of Mathematics and Natural Sciences,
Yogyakarta State University

**Corresponding Author*

e-mail: karinasyahrulh.2025@student.uny.ac.id ^{*1)}, laifa.rahmawati@uny.ac.id ²⁾

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ABSTRACT

Problem-solving skills are essential competencies that need to be developed in 21st-century science learning. This study aims to examine the effectiveness of the Problem-Based Learning (PBL) model in improving problem-solving skills through a Systematic Literature Review (SLR). This review examined 17 primary empirical research articles from the Scopus database published between 2020 and 2026. The findings indicate that PBL has a positive impact on students' problem-solving skills. The implementation of PBL combined with STEM, electronic student worksheets (e-LKPD), PhET simulations, learning modules, computer simulations, and digital books represents a range of strategies used to support problem-solving skills. The reported skills that developed include understanding problems, formulating or planning solutions, implementing problem-solving plans, and evaluating and reflecting on solutions. Nevertheless, outcomes for each aspect varied across studies; therefore, the effectiveness of PBL should be interpreted in relation to the characteristics of the intervention, educational level, and indicators measured. This review provides an overview of the potential of PBL and its implementation variations for developing problem-solving skills in science learning.

Keywords: PBL; problem-solving skills; science learning

INTRODUCTION

Meeting the challenges of the 21st century requires essential competencies in learning, one of which is problem-solving skills. Trilling and Fadel (2009) state that these skills emphasize solving problems encountered in complex life situations. Problem-solving skills can train students to understand and address problems when facing future challenges (Knöpfel et al., 2024). Problem-solving activities require students to identify, explore, and understand problems, plan solutions, determine and implement the best solution, and then evaluate it (OECD, 2024).

In practice, problem-solving skills remain low. The results of the 2022 Programme for International Student

Assessment (PISA) indicate that Indonesian students' problem-solving skills are still low (OECD, 2024). Leite and Dourado (2013) explain that low problem-solving skills are associated with several factors, including laboratory activities that remain verification-based, limited investigative activities, and learning that does not connect subject matter with real-world problems. Another factor is the lack of engaging teaching materials to facilitate learning, while teacher explanations tend to be verbal without the support of interactive media (Roosyanti & Larasati, 2026).

In addition, teacher-centered instruction leaves students insufficiently prepared to deal with real-world problems (Damayanti et al., 2021). As a result, students understand learning concepts mainly through memorization and do not

yet apply science concepts in everyday life. An appropriate learning model or approach is therefore needed to engage students in scientific thinking and problem-solving. One model considered effective for improving problem-solving skills is Problem-Based Learning (PBL). Hmelo-Silver (2004) explains that PBL presents complex and authentic problem-solving activities at the beginning of learning, after which students apply science concepts to solve the problems (Etherington, 2011).

The theoretical relationship between PBL and problem-solving can be explained by the alignment between the PBL learning process and Polya's (1973) four stages. Authentic problems encourage students to interpret a situation and identify what is known and unknown (understanding the problem). Organizing students and planning investigations encourage them to select information, formulate strategies, and justify possible solution steps (devising a plan). Guided individual or group investigations allow students to carry out their plans, collect evidence, and revise their actions when the evidence does not support their initial ideas (carrying out the plan). Finally, presenting, discussing, and evaluating solutions can encourage students to check their answers, consider limitations, and reflect on their process (looking back) (Hmelo-Silver, 2004; Polya, 1973).

Learning that applies the PBL model has been shown to improve problem-solving skills (Hidaayatullaah et al., 2020). The advantages of PBL include promoting active learning; developing critical thinking, collaboration, and communication skills relevant to surrounding problems; and increasing students' learning motivation (Nicholus et al., 2023). PBL can also encourage students to conduct in-depth investigations

consistent with constructivism and develop collaborative, problem-solving-based thinking, thereby preparing them to face future challenges (Uluçınar, 2023).

Although previous reviews have examined the general effectiveness of PBL or particular variations—including a review of innovative PBL strategies (Simatupang et al., 2026) and a recent SLR focused on science learning at the junior secondary level (Setyawan et al., 2026)—their scopes and synthesis approaches differ. This review does not claim to be the first review of PBL and problem-solving. Its intended contribution is to organize findings from selected Scopus-indexed literature according to (a) Polya's four problem-solving stages, (b) learning features and instructional-material innovations reported alongside PBL, and (c) the educational levels represented. This stage-oriented mapping is descriptive: it does not calculate a pooled effect size or establish that one PBL innovation is superior to another. A positive result in one study is not equivalent to evidence of statistically significant superiority over an alternative PBL format. The research questions are as follows:

1. Which aspects of problem-solving skills have developed most optimally, and which need further improvement?
2. How effective is the implementation of Problem-Based Learning (PBL) in improving students' problem-solving skills in science learning?
3. What trends can be identified in integrating Problem-Based Learning (PBL) with various learning approaches in science education research?
4. How does the implementation of the PBL model affect the improvement of students' problem-solving skills?

METHOD

A Systematic Literature Review (SLR) is a literature-review approach conducted systematically, transparently, reproducibly, and structurally to identify and synthesize relevant research evidence in order to answer a particular question or address a specific topic or phenomenon (Booth et al., 2021). This study used an SLR to collect, evaluate, and synthesize literature from research on implementing Problem-Based Learning (PBL) to improve students' problem-solving skills in science learning.

The literature search was conducted using the Scopus database, and study selection followed the PRISMA reporting framework. The search source and selection procedures define the scope of this review; articles from other databases, including studies published in Eduproxima, are cited

only as contextual literature and are not counted among the 17 selected articles. Articles were retrieved using Publish or Perish (PoP). Search terms included "Problem Based Learning," "PBL," "Problem Solving Skill," and "Science Learning."

The inclusion criteria for scholarly articles were: (1) publication between 2020 and 2026; (2) peer-reviewed publication; (3) discussion of PBL implementation for students' problem-solving in science learning; (4) examination of PBL integration with other innovative learning approaches or strategies; and (5) availability in English. Articles meeting these criteria proceeded to analysis and synthesis. The selected articles were analyzed in accordance with PRISMA guidance. The stages are presented in Figure 1.

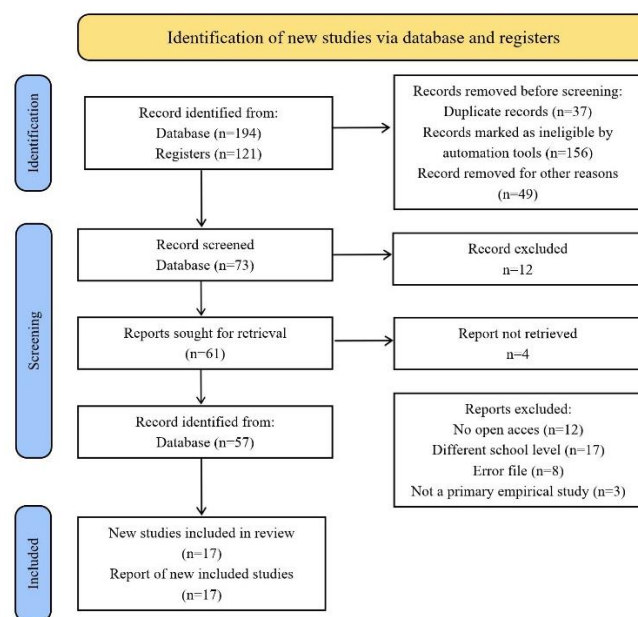


Figure 1. PRISMA Flow Diagram (Page et al., 2021)

The Scopus search identified 194 journal records, while 121 unpublished journal records were also obtained. Before screening, records were removed according to specified criteria. A total of 37 duplicate

records were removed; 156 records were then automatically flagged as not meeting the criteria, and 49 records were removed for other reasons. After screening, 73 records remained for processing. Twelve

records were not included in this analysis. Of the 61 records sought for retrieval, only 57 were considered eligible for inclusion in the analysis. Additional screening was then conducted on the assessed reports. Twelve records were excluded because full text was not openly accessible, 17 because their study populations were outside the elementary-to-senior-secondary levels, eight because of file errors, and three because they were not primary empirical

studies. Following selection and screening, 17 articles were included in this review.

RESULTS AND DISCUSSION

The scientific articles retrieved from Scopus were used to categorize publications from the international database. A summary of previous studies relevant to this review is presented in Table 1.

Table 1. Summary of the Studies Reviewed

No.	Author/Year	Dependent Variable	Learning Model	Educational Level	Findings
1.	Martaningsih et al. (2022)	Problem-solving skills	PBL-STEM model with a module	Elementary	The PBL-STEM module helps students understand everyday problems from multiple perspectives.
2.	Winarto et al. (2025)	Problem-solving skills and environmental awareness	PBL model with e-LKPD integrated with local potential	Junior secondary	The problem-solving aspects reported to improve significantly through PBL with locally contextualized e-LKPD were understanding the problem and planning a solution.
3.	Saputri et al. (2025)	Problem-solving skills	PBL model with e-LKPD and PhET	Junior secondary	Problem-Based Learning supported by PhET (Physics Education Technology) can improve students' problem-solving skills.
4.	Agustoni et al. (2021)	Problem-solving skills	Contextual Problem-Based Learning (CPBL)	Elementary	Contextual Problem-Based Learning instructional tools can improve problem-solving skills.
5.	Damayanti et al. (2021)	Problem-solving skills	PBL model with a science module	Junior secondary	<ul style="list-style-type: none"> Problem-solving skills can improve through a PBL-based science module. The aspect reported to improve significantly was problem identification.
6.	Santuthi et al. (2020)	Problem-solving skills and critical-thinking skills	PBL model	Junior secondary	PBL can improve problem-solving and critical-thinking skills.
7.	Aslan & Duruhan (2021)	Problem-solving skills	PBL model with a Virtual Learning Environment (VLE)	Junior secondary	PBL with a virtual learning environment can improve students' thinking skills.

No.	Author/Year	Dependent Variable	Learning Model	Educational Level	Findings
8.	Amanda et al. (2023)	Problem-solving skills	PBL model using a Complexity Science approach	Senior secondary	The CS-PBL model can improve students' critical-thinking and problem-solving skills.
9.	Monsang et al. (2021)	Problem-solving skills	PBL model	Junior secondary	<i>Problem-Based Learning is effective in improving secondary students' science problem-solving skills in Thailand.</i>
10.	Alfiana et al. (2021)	Problem-solving skills	PBL-STEM model with lesson plans and ILAU	Senior secondary	PBL-STEM lesson plans and ILAU with formative assessment can improve students' problem-solving skills.
11.	Hidaayatullaah et al. (2020)	Problem-solving skills	PBL model	Senior secondary	Students' problem-solving skills improved through the implementation of PBL.
12.	Treepob et al. (2023)	Problem-solving skills	PBL model	Junior secondary	PBL promotes the development of students' scientific problem-solving skills.
13.	Prahani et al. (2022)	Problem-solving skills	PBL model with a 3D digital book	Senior secondary	Online PBL assisted by a digital-book application with 3D animation improves students' problem-solving skills.
14.	Gök & Boncukçu (2023)	Problem-solving skills and environmental literacy	PBL model with an e-module	Junior secondary	PBL effectively improves junior secondary students' problem-solving skills and environmental literacy in Şanlıurfa, Türkiye.
15.	Fitriani et al. (2020)	Problem-solving skills and self-efficacy	PBL-POE model	Senior secondary	The PBL-POE model is effective in improving students' problem-solving skills and self-efficacy.
16.	Parno et al. (2021)	Problem-solving skills	PBL-STEM model	Senior secondary	Integrating PBL and STEM can improve students' thinking skills.
17.	Simanjuntak et al. (2021)	Problem-solving skills and creative-thinking skills	PBL model with computer simulations	Senior secondary	<ul style="list-style-type: none"> • The problem-solving aspect reported to improve significantly was formulating solutions. • Combining PBL with computer simulations can improve problem-solving and creative-thinking skills.

1. Which aspects of problem-solving skills have developed most optimally, and which need further improvement?

Polya (1973) identifies several aspects of problem-solving skills that

students should possess: understanding the problem, devising a plan, carrying out the plan, and evaluation and reflection.

Based on the analysis of the articles above, the PBL model can

improve students' problem-solving skills; however, not all aspects have developed optimally. The 17 studies reviewed yielded the following findings:

a. Understanding the problem

Seven studies indicate that students were able to understand and identify complex, contextual problems while actively searching for and gathering the information needed to understand those problems more deeply (Martaningsih et al., 2022; Winarto et al., 2025; Damayanti et al., 2021; Monsang et al., 2021; Hidaayatullaah et al., 2020; Prahani et al., 2022; Parno et al., 2021).

b. Planning a problem-solving approach

Six studies report that students were able to design possible solutions through discussion and exploration. Students were also able to analyze information, develop strategic steps for formulating alternative solutions, and determine appropriate problem-solving methods (Winarto et al., 2025; Damayanti et al., 2021; Monsang et al., 2021; Hidaayatullaah et al., 2020; Prahani et al., 2022; Simanjuntak et al., 2021). These findings are consistent with Sapitri et al. (2024), who reported achievement rates of 90.62% for understanding the problem and 84.37% for planning a solution in PBL-based biotechnology learning. This difference indicates variation in achievement across stages, although the results cannot be generalized because of differences in context, instruments, and participant characteristics.

c. Carrying out the problem-solving plan

Four studies report that students were able to implement the solutions they had designed (Amanda et al., 2023; Monsang et al., 2021; Fitriani et al., 2020; Simanjuntak et al., 2021). This finding indicates that implementing solutions is one aspect of problem-solving skills developed through problem-based learning.

Meanwhile, eight studies identify evaluation and reflection as components of problem-solving that still require strengthening (Amanda et al., 2023; Saputri et al., 2025; Alfiana et al., 2021; Hidaayatullaah et al., 2020; Monsang et al., 2021; Santuthi et al., 2020; Simanjuntak et al., 2021; Treepob et al., 2023).

Setyawan et al. (2026) describe the relationship between PBL stages and Polya's problem-solving indicators, including the importance of evaluation for reflecting on solution effectiveness. PBL should be designed so that investigation and solution implementation are followed by explicit, evidence-based evaluation and reflection. Learning should therefore provide more practice in comparing alternative solutions using evidence, identifying weaknesses in strategies, and reflecting on results to determine necessary improvements.

2. How effective is the implementation of Problem-Based Learning (PBL) in improving students' problem-solving skills in science learning?

PBL is a learning model that has been shown to effectively improve various skills needed to face future challenges, including problem-solving

skills. The literature review identified several key characteristics of PBL, including:

- a. Presenting authentic and contextual problems at the beginning of learning.
Authentic and contextual problems in PBL encourage students to identify problems, gather information, and formulate solutions, thereby supporting the development of problem-solving skills through meaningful learning (Diana & Natadiwijaya, 2026).
- b. Positioning students at the center of learning.
Students must play an active role in solving problems, while the teacher

acts only as a facilitator (Simatupang et al., 2026).

- c. The need for communication and collaboration
Good communication fosters effective collaboration among students, enabling them to build a shared conceptual understanding while solving problems (Dewi et al., 2026).
- d. Independence
The PBL model encourages students to explore independently when solving problems (Damayanti et al., 2021).

The effective implementation of PBL involves several stages, as shown in Figure 2 (Agustoni et al., 2021).

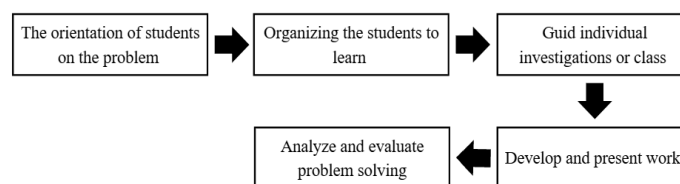


Figure 2. Stages of PBL

a. Orienting students to the problem

At this stage, students are presented with a contextual problem related to everyday life, prompting curiosity and a desire to solve it.

b. Organizing students for learning

The class is divided into groups to determine ways to solve the problem. The teacher helps define and organize learning tasks related to the problem.

c. Guiding individual and group investigations

This is the core stage of PBL, in which students actively analyze information and determine appropriate solutions based on the information obtained. Several studies use learning tools and instructional materials to support PBL implementation, as shown in Table 2.

Table 2. PBL Innovations Identified in the Reviewed Articles

Innovation	Author
PBL-STEM model with a module	Martaningsih et al. (2022)
PBL model with e-LKPD integrated with local potential	Winarto et al. (2025)
PBL model with e-LKPD	Saputri et al. (2025)
Contextual Problem-Based Learning (CPBL) model with instructional tools	Agustoni et al. (2021)

Innovation	Author
PBL model with a science module	Damayanti et al. (2021)
PBL model with a Virtual Learning Environment (VLE)	Aslan & Duruhan (2021)
PBL model using a Complexity Science approach	Amanda et al. (2023)
PBL-STEM model with lesson plans and ILAU	Alfiana et al. (2021)
PBL model with a 3D digital book	Prahani et al. (2022)
PBL model with an e-module	Gök & Boncukçu (2023)
PBL-POE model (Problem-Based Learning–Predict, Observe, Explain)	Fitriani et al. (2020)
PBL-STEM model	Parno et al. (2021)
PBL model with computer simulations	Simanjuntak et al. (2021)

Most studies introduced innovations to the PBL model in order to improve students' problem-solving skills. Fitriani et al. (2020), for example, explain that PBL-POE connects prediction, observation, and explanation based on evidence. Setyawan et al. (2026) identify links between PBL stages and problem-solving skill indicators. These findings suggest that PBL effectiveness is associated not only with presenting problems but also with implementing each learning stage that helps students understand problems, plan solutions, apply strategies, and evaluate outcomes.

d. Developing and presenting the work

After conducting an investigation, students identify their best solution and present their work individually or in groups (Winarto et al., 2025).

e. Analyzing and evaluating the problem-solving process

In the final stage of PBL, students evaluate the effectiveness of the selected solution and reflect on it (Damayanti et al., 2021; Amanda et al., 2023; Saputri et al., 2025).

Several studies included in this synthesis reported positive outcomes from implementing Problem-Based Learning (PBL) integrated with digital

technology or other instructional approaches. For example, Simanjuntak et al. (2021) found that PBL assisted by computer simulations resulted in statistically better problem-solving skills than PBL alone and conventional instruction. Meanwhile, Prahani et al. (2022) reported that online PBL assisted by a digital book featuring 3D animations was effective in improving students' physics problem-solving skills. However, these findings should be interpreted in light of each study's research design and comparison groups. Thus, the findings suggest the potential benefits of integrating PBL with supporting technologies, but they do not establish that such integration is consistently more effective than PBL alone across different learning contexts.

3. What trends can be identified in innovative Problem-Based Learning (PBL) strategies in science learning?

Trends in innovative PBL strategies in science learning have developed in response to the needs of 21st-century education. PBL is no longer used only as a standalone learning model; it is increasingly developed through innovative learning strategies involving digital technology, different learning approaches, instructional materials, and learning tools. The

categories of instructional innovation identified in the literature are presented in Table 3.

Table 3. Categories of PBL Innovation

No.	Innovation Category	Articles
1	PBL and Technology Use	a. Winarto et al. (2025): PBL with e-LKPD integrated with local potential b. Saputri et al. (2025): PBL with e-LKPD c. Aslan & Duruhan (2021): PBL with a Virtual Learning Environment (VLE) d. Prahani et al. (2022): PBL with a 3D digital book e. Gök & Boncukçu (2023): PBL with an e-module f. Simanjuntak et al. (2021): PBL with computer simulations
2	PBL Integrated with Learning Approaches	a. Amanda et al. (2023): PBL using a Complexity Science approach b. Fitriani et al. (2020): PBL-POE (Problem-Based Learning–Predict, Observe, Explain) c. Parno et al. (2021): PBL-STEM
3	PBL with Instructional Materials	a. Martaningsih et al. (2022): PBL-STEM with a module b. Damayanti et al. (2021): PBL with a science module
4	PBL with Learning Tools	a. Agustoni et al. (2021): Contextual Problem-Based Learning (CPBL) with instructional tools b. Alfiana et al. (2021): PBL-STEM with lesson plans and ILAU

The categories of innovation are also illustrated in Figure 3.

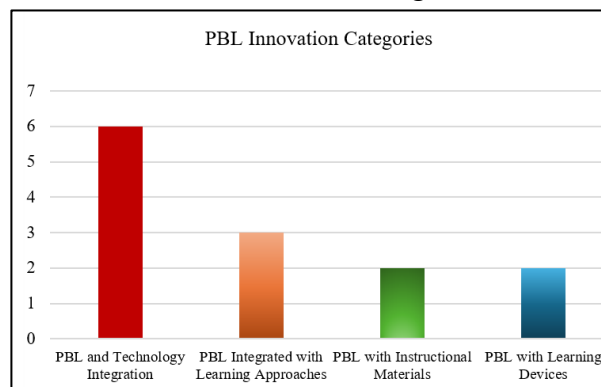


Figure 3. Diagram of PBL Innovation Categories

As shown in the diagram, the most dominant innovation is the use of digital technology, such as e-LKPD, e-modules, Virtual Learning Environments (VLE), and 3D digital books. These technologies are intended to increase motivation and make students' problem-solving activities more interactive.

Another trend is integrating PBL with learning approaches such as Complexity Science, POE, and STEM.

These integrations aim to complement the structure of PBL, improve students' collaboration, communication, and independence, and help them connect concepts with real-world problems (Fitriani et al., 2020).

Another trend is the development of PBL-based instructional materials, including science modules and PBL-STEM modules. These materials are designed to improve students' problem-solving skills. Learning tools

have also been developed, including lesson plans, ILAU student activity sheets, and contextual learning resources systematically designed to optimize PBL implementation (Alfiana et al., 2021).

4. How does the implementation of the PBL model affect the improvement of students' problem-solving skills in science learning?

Based on the review of 17 Scopus-indexed articles, PBL consistently shows a positive association with students' problem-solving skills across elementary, junior secondary, and senior secondary education. The implementation of PBL reported in the 17 articles is presented in Figure 4.

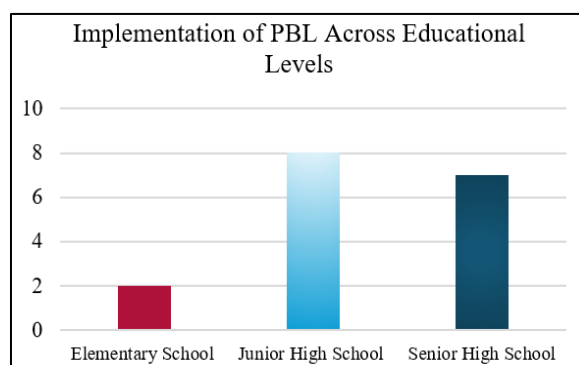


Figure 4. Implementation of PBL at Each Educational Level

PBL can be applied to improve students' problem-solving skills at every educational level. This is supported by Santuthi et al. (2020) and Prahani et al. (2022), who reported positive effects of PBL on problem-solving skills. Monsang et al. (2021) also found that PBL positively affects problem-solving ability. In addition, Aslan and Duruhan (2021) emphasize that PBL can improve students' learning motivation, collaboration, communication, and independence. Thus, its effects are not limited to cognitive aspects but also include affective aspects. The effects of PBL at each educational level are described below:

a. Elementary School

Several studies reviewed indicate that PBL is effective in improving problem-solving skills (Dewi et al., 2026). In addition, PBL-STEM modules can improve elementary students' analytical and problem-solving skills (Martaningsih et al.,

2022). Agustoni et al. (2021) state that the Contextual Problem-Based Learning (CPBL) model, supported by learning tools, can connect science concepts with contextual real-life problems. PBL has a positive effect on elementary students' problem-solving skills.

b. Junior Secondary School

PBL is more frequently implemented at the junior secondary level. Innovations at this level include science modules, e-LKPD, and Virtual Learning Environments (VLE). These instructional materials make learning more active and structured. Materials integrated with local potential further increase students' engagement in solving problems relevant to everyday life (Winarto et al., 2025). In addition to improving junior secondary students' problem-solving skills, PBL can also influence critical-thinking skills and

environmental literacy (Gök & Boncukçu, 2023).

c. Senior Secondary School

Unlike at the elementary and junior secondary levels, PBL at the senior secondary level is often combined with various approaches and digital technologies to expand opportunities for independent exploration and investigation (Prahani et al., 2022). Integrating PBL with

Complexity Science can improve senior secondary students' critical-thinking and problem-solving skills, helping them address a range of future challenges. Parno et al. (2021) report that PBL has a strong positive effect on senior secondary students' problem-solving skills because students analyze and evaluate decisions made in authentic, contextual science problems.

CONCLUSION

Based on a Systematic Literature Review of 17 primary empirical research articles indexed in Scopus and published between 2020 and 2026, Problem-Based Learning (PBL) shows positive potential for improving students' problem-solving skills in science learning at the elementary, junior secondary, and senior secondary levels. PBL, whether implemented independently or integrated with STEM, POE, Complexity Science, instructional materials, and digital technology, has been reported to develop various aspects of problem-solving. In terms of Polya's stages, understanding the problem and planning a solution were

frequently reported to improve, whereas evaluation and reflection still require further strengthening.

The effectiveness of PBL depends on instructional design, implementation of each stage, support from instructional materials and technology, and alignment between learning activities and the indicators measured. However, this descriptive synthesis cannot establish the magnitude of the PBL effect or determine the superiority of one intervention variation over another. Future research should measure each aspect of problem-solving in detail and estimate PBL effects quantitatively.

REFERENCES

- Agustoni, A., Suratno, & Suparti. (2021). Development of science learning devices contextual problem based learning (CPBL) based in improving problem solving skills for 4th grade elementary school. *Journal of Physics: Conference Series*, 1839(1), 012029. <https://doi.org/10.1088/1742-6596/1839/1/012029>
- Alfiana, R., Parno, & Yogihati, C. I. (2021). Development of ILAU based on PBL-STEM model with formative assessment as an opportunity to improve problem solving skills in heat and temperature topics. *Journal of Physics: Conference Series*, 1747(1), 012005. <https://doi.org/10.1088/1742-6596/1747/1/012005>
- Amanda, F. F., Sumitro, S. B., Lestari, S. R., & Ibrohim, I. (2023). Enhancing Critical Thinking And Problem Solving Skills By Complexity Science-Problem Based Learning Model. *Multidisciplinary Journal of Educational Research*, 1–19. <https://doi.org/10.17583/remie.9409>
- Aslan, S. A., & Duruhan, K. (2021). The effect of virtual learning

- environments designed according to problem-based learning approach to students' success, problem-solving skills, and motivations. *Education and Information Technologies*, 26(2), 2253–2283. <https://doi.org/10.1007/s10639-020-10354-6>
- Booth, A., Sutton, A., & Clowes, M. (2021). *Systematic approaches to a successful literature review*. SAGE Publications.
- Damayanti, J., Sueb, & Rohman, F. (2021). *Students' problem-solving skills through problem based learning module: Macrozoobenthos as bioindicator water quality module*. 030025. <https://doi.org/10.1063/5.0043584>
- Dewi, S. K., Kuswandi, D., Pristiani, R., Kusumaningrum, S. R., & Mardhatillah. (2025). The need analysis for PBL-based e-book learning with AR to enhance digital literacy and problem solving skills of elementary school. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 7(4). <https://jurnal.stkipgritlungagung.ac.id/index.php/eduproxima/article/view/7781>
- Diana, D., & Natadiwijaya, I. F. (2026). Development of a PBL module based on socio-scientific issues (SSI) involving the use of food additives to improve junior secondary students' problem-solving skills and collaboration. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 8(3), 2787–2798. <https://doi.org/10.29100/eduproxima.v8i3.9995>
- Etherington, M. B. (2011). Investigative Primary Science: A Problem-based Learning Approach. *Australian Journal of Teacher Education*, 36(9). <https://doi.org/10.14221/ajte.2011v36n9.2>
- Fitriani, A., Zubaidah, S., Susilo, H., & Muhdhar, M. H. I. A. (2020). The Effects of Integrated Problem-Based Learning, Predict, Observe, Explain on Problem-Solving Skills and Self-Efficacy. *Eurasian Journal of Educational Research*, 20(85), 45–64. <https://doi.org/10.14689/ejer.2020.85.3>
- Gök, G., & Boncukçu, G. (2023). The Effect Of Problem-Based Learning on Middle School Students' Environmental Literacy and Problem-Solving Skills. *Journal of Science Learning*, 6(4), 414–423. <https://doi.org/10.17509/jsl.v6i4.62781>
- Hidaayatullaah, H. N., Dwikoranto, & Suprpto, N. (2020). Implementation of Problem Based Learning to Train Physics Students' Problem Solving Skills. *Journal of Physics: Conference Series*, 1491(1), 012053. <https://doi.org/10.1088/1742-6596/1491/1/012053>
- Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, 16(3), 235–266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Knöpfel, M., Kalz, M., & Meyer, P. (2024). General Problem-solving Skills Can be Enhanced by Short-time Use of Problem-Based Learning (PBL). *Journal of Problem Based Learning in Higher Education*. <https://doi.org/10.54337/ojs.jpblhe.v12i1.7871>
- Leite, L., & Dourado, L. (2013). Laboratory Activities, Science Education and Problem-solving Skills. *Procedia - Social and Behavioral Sciences*, 106,

- 1677–1686. <https://doi.org/10.1016/j.sbspro.2013.12.190>
- Martaningsih, S. T., Maryani, I., & Prasetya, D. S. (2022). Stem Problem-Based Learning Module: A Solution to Overcome Elementary Students' Poor Problem-Solving Skills. *Pegem Journal of Education and Instruction*, 12(4).
- Monsang, P., Srikoon, S., & Wichaino, N. (2021). The effects of problem based learning for enhancing science problem solving skills. *Journal of Physics: Conference Series*, 1835(1), 012016. <https://doi.org/10.1088/1742-6596/1835/1/012016>
- Nicholus, G., Muwonge, C. M., & Joseph, N. (2023). The Role of Problem-Based Learning Approach in Teaching and Learning Physics: A Systematic Literature Review. *F1000Research*, 12, 951. <https://doi.org/10.12688/f1000research.136339.2>
- OECD. (2024). *PISA 2022 Results (Volume V): Learning Strategies and Attitudes for Life*. OECD Publishing. <https://doi.org/10.1787/c2e44201-en>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Parno, Anggraini, R. T., Hidayat, A., Fauziyah, S., Pramono, N. A., Supriana, E., & Ali, M. (2021). The Building of Students' Problem Solving Skills through STEM Aproach with Virtual Simulation Media. *Journal of Physics: Conference Series*, 1842(1), 012073. <https://doi.org/10.1088/1742-6596/1842/1/012073>
- Polya, G. (1973). *How to Solve It: A New Aspect of Mathematical Method*. Princeton University Press.
- Prahani, B. K., Rizki, I. A., Nisa', K., Citra, N. F., Alhusni, H. Z., & Wibowo, F. C. (2022). Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject. *Journal of Technology and Science Education*, 12(2), 379. <https://doi.org/10.3926/jotse.1590>
- Roosyanti, A., & Larasati, D. A. (2026). *Integration of Computational Thinking in Natural and Social Science Learning in Elementary Schools to Improve Problem Solving Skills*. 12(1).
- Santuthi, P. C. P., Suardana, N., & Wijana, N. (2020). The Effect of Problem Based Learning Learning Model on Problem Solving and Critical Thinking Ability of Class Viii Students in Smpn 1 Singaraja of Science. *Journal of Physics: Conference Series*, 1503(1), 012046. <https://doi.org/10.1088/1742-6596/1503/1/012046>
- Sapitri, D., Hayat, M. S., & Rachmawati, F. (2024). Improving problem-solving skills and cognitive learning outcomes in biotechnology through Problem-Based Learning in the Merdeka Curriculum. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 6(2). <https://jurnal.stkippgritulungagung.ac.id/index.php/eduproxima/article/view/4437>
- Saputri, R., Wilujeng, I., Suyanta, S., Nurohman, S., Jumadi, J., Ilafi, M. M., & Purnama, A. Y. (2025).

- Improving problem-solving skills through the physics education technology assisted problem based learning model electronic student worksheets. *Revista Mexicana de Física E*, 22(2 Jul-Dec). <https://doi.org/10.31349/RevMexFisE.22.020213>
- Setyawan, J., Trisnowati, E., & Singgih, S. (2026). The effectiveness of PBL in improving junior secondary students' problem-solving skills in science learning: An SLR of 2016–2025. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 8(2). <https://jurnal.stkippgritulungagung.ac.id/index.php/eduproxima/article/view/9375>
- Simatupang, H. A., Winarto, & Wilujeng, I. (2026). Developing problem-solving skills through PBL: A literature review of innovative learning strategies. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 8(1). <https://jurnal.stkippgritulungagung.ac.id/index.php/eduproxima/article/view/8491>
- Treepob, H., Hemtasin, C., & Thongsuk, T. (2023). Development of Scientific Problem-Solving Skills in Grade 9 Students by Applying Problem-Based Learning. *International Education Studies*, 16(4), 29. <https://doi.org/10.5539/ies.v16n4p29>
- Trilling, B., & Fadel, C. (2009). 21st century skills: Learning for life in our times. Jossey-Bass/Wiley.
- Uluçınar, U. (2023). The Effect of Problem-Based Learning in Science Education on Academic Achievement: A Meta-Analytical Study. *Science Education International*, 34(2), 72–85. <https://doi.org/10.33828/sei.v34.i2.1>
- Winarto, Putri, A. F., Fahrezy, M., Arti, Y., Kristyaningrum, D. H., Rahayu, R., Ariyatun, & Hayu, W. R. R. (2025). How to improve students' problem-solving skills and environmental awareness: A study of the impact of worksheet problem-based learning on local potential of landfills Bantul region. *Multidisciplinary Science Journal*, 7(12), 2025564. <https://doi.org/10.31893/multiscience.2025564>
- Yanto, F., Festiyed, F., & Enjoni, E. (2021). Problem Based Learning Model For Increasing Problem Solving Skills In Physics Learning. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, 6(1), 53. <https://doi.org/10.26737/jipf.v6i1.1870>