

PBL IN IMPROVING STUDENT LEARNING OUTCOMES AND COLLABORATION IN ELEMENTARY SCIENCE LEARNING: A SLR

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Article history:

Submitted: MM. DDth, YY; Revised: MM. DDth, YY; Accepted: MM. DDth, YY; Published: MM. DDth, YY

ABSTRACT

Science learning is not only about mastering concepts, but also training scientific and analytical thinking skills. The concept of science is often abstract so that it involves observation, experimentation, and discussion. Collaboration skills therefore constitute a fundamental competency required to navigate and succeed in the demands of the 21st century. PBL is an instructional approach that uses authentic, real-world problems as the starting point for learning, which can contribute to improved learning outcomes and stronger collaboration among students. This study investigates the effectiveness of PBL in enhancing elementary students' science learning outcomes and collaboration skills using the PRISMA protocol. The article studied is a publication for the period 2016–2026 so that the findings directly respond to the most up-to-date elementary science learning context. Data is obtained through *Publish or Perish* and Vosviewer to display data visualizations. Articles were selected based on the completeness of the article, the sinta index 1-2 and scopus so that 21 literature was obtained. The results of a review of 21 literature confirm that PBL can improve learning outcomes. The integration of digital technology shows a tendency to increase the effectiveness of PBL compared to without technological support. These results suggest that integrating PBL with interactive media enhances the visualization of abstract scientific concepts while also promoting greater cognitive engagement among students.

Keywords: PBL; learning outcomes; collaboration; science learning; elementary school

INTRODUCTION

Science education in elementary schools plays a crucial role in providing students with foundational knowledge about natural phenomena. Science learning is not only about mastering concepts, but also training scientific and analytical thinking skills (Fitria & Zan, 2023). However, evidence from classroom practice indicates that elementary students' science learning outcomes remain a persistent concern. Various studies show that the majority of students have difficulty in understanding the concept of science which has an impact on learning outcomes. Based on data from PISA and TIMS, indicates that the scientific competencies of Indonesian students remain below the average of participating countries,

highlighting the urgent need for transformation in instructional practices (Afriansyah et al., 2025).

Science concepts, which are often abstract, require bridges in the form of activities that involve observation, experimentation, and discussion. Without an active and contextual learning experience, students will have difficulty building a deep understanding, and learning science risks becoming a mere memorization that is easy to forget and has an impact on learning outcomes (Malik et al., 2026). In addition, the collaboration skills that are the foundation in the 21st century have not been maximized in learning process (Oktavia et al., 2024). In fact, this ability is vital to communicate effectively, and solve problems together in

social and professional contexts in the future. Previous studies on Problem-Based Learning (PBL) in science education predominantly emphasize learning outcomes, with collaboration skills remaining underexplored, particularly at the elementary level. Therefore, this study employs a systematic literature review (SLR) to synthesize the effectiveness of PBL in enhancing both learning outcomes and collaboration skills.

Various learning model innovations have been developed and implemented. One of the models that has received wide attention from education researchers and practitioners is *Problem Based Learning* (PBL). This model uses authentic, context-based problems as the initial trigger for the learning process, so that students are encouraged to actively identify problems, design solutions, carry out investigations, and communicate their findings collaboratively within the group (Sajidan et al., 2022). This research is based on the theory of social constructivism, which emphasizes that knowledge is built through social interaction and collaboration. Within this framework, PBL facilitates meaningful learning by engaging students in problem-solving, discussion, and knowledge construction activities together, which in turn improves cognitive learning outcomes and collaboration skills (Vygotsky, 1978). Thus, PBL has great potential to change the paradigm of science learning from passive to active, relevant, and meaningful for elementary school students.

Previous research has consistently shown the effectiveness of PBL on cognitive learning outcomes at the elementary school level. Students taught by teachers who have received PBL training experience a significant

improvement in the ability to apply knowledge compared to students taught using traditional learning methods (Alreshidi & Lally, 2024). The research focus on PBL is not only in the cognitive realm, but has penetrated into the affective realm, one of which is collaboration. Research on PBL also has a positive impact on student collaboration as shown by the ability to collaborate, share roles, express opinions, respect opinions, and complete tasks effectively (Mandalika et al., 2024).

Although many studies have examined the effectiveness of PBL, there are still some limitations that need to be overcome. Most studies tend to focus on just one variable, such as improved cognitive learning outcomes or collaboration alone. In fact, in classroom learning practice, the two competencies develop simultaneously and influence each other. In addition, it was found that most of the literature reviews on PBL in elementary science use the conventional literature review approach which tends to be susceptible to selection bias because it does not have a standard protocol in the selection and evaluation of articles. Meanwhile, a more rigorous and structured The application of a Systematic Literature Review (SLR) guided by the PRISMA protocol, accompanied by clearly defined inclusion and exclusion criteria, remains relatively limited, despite its potential to identify research gaps and uncover areas that have not yet been sufficiently explored. The identification of these gaps becomes a conceptual and methodological basis for further research to be more directed, relevant, and contribute to scientific novelty (Mutiarra et al., 2024).

This study is an SLR that specifically examines the effectiveness of

PBL to improving student learning outcomes and collaboration skills in science learning at the elementary school level using the PRISMA protocol. The articles studied are published in the 2016–2026 time span so that the findings directly respond to the most up-to-date elementary science learning context, including post-pandemic learning dynamics and teachers' adaptation to the times. This time span was chosen to ensure that the resulting synthesis is actual and relevant to the real challenges faced by educators. This study is strengthened by a *bibliometric analysis* study to map keywords as a reference to find research gaps and research contributions. This novelty is expected to provide a meaningful contribution to the advancement of both theoretical and practical perspectives in elementary science education.

The main objective of SLR is to systematically analyze the effectiveness of the PBL in improving student learning outcomes and collaboration skills in science learning in primary schools. The findings of this review are expected to offer deeper insight into how PBL supports multiple dimensions of learning, identify effective practices, and generate practical recommendations for educators and researchers seeking to enhance the quality of science instruction in elementary schools.

METHODS

This study uses a SLR combined with *Bibliometric Analysis*. SLR uses the in-depth identification, screening, and analysis of relevant scientific articles to answer research *questions* (Xiao & Watson, 2019). SLR is a systematic study to collect, select, and analyze relevant literature on a research topic with an

objective, structured, and replicable approach to produce holistic and minimally biased conclusions (Asmi et al., 2022; Page et al., 2021).

Bibliometric analysis is a systematic approach to examining scholarly literature in order to reveal patterns, research trends, and the scholarly influence within a specific field of study (Passas, 2024). Bibliometric analysis uses large-scale and objective scientific data, which is analyzed through quantitative and qualitative approaches to map the development of a field. This method helps researchers understand the structure of knowledge, find research gaps, formulate new ideas, and strategically position research contributions (Donthu et al., 2021).

Research Questions (RQ) are used to develop research and provide a clear focus and scope. The RQ used in this study is (1) what is the trend of research publications on PBL in improving student learning outcomes and collaboration in elementary science learning in the period 2016–2026?; (2) What are the dominant keywords in PBL research in improving student learning outcomes and collaboration in elementary science learning?; (3) What are the implications of PBL research results in improving student learning outcomes and collaboration in elementary science learning.

This study employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The PRISMA approach was adopted to ensure a systematic, transparent, and rigorous review process (Page et al., 2021). This protocol functions as a methodological sign that systematically regulates the stages of literature search and selection. The protocol contains clear criteria and procedures for tracing sources,

filtering based on predetermined parameters, and determining studies that are worthy of inclusion in the analysis (Paschou et al., 2020) (Güzel et al., 2024). The PRISMA flow has four stages, namely *identification*, *screening*, *eligibility*, and *inclusion* which can be seen in figure 1 (Zhong et al., 2022).

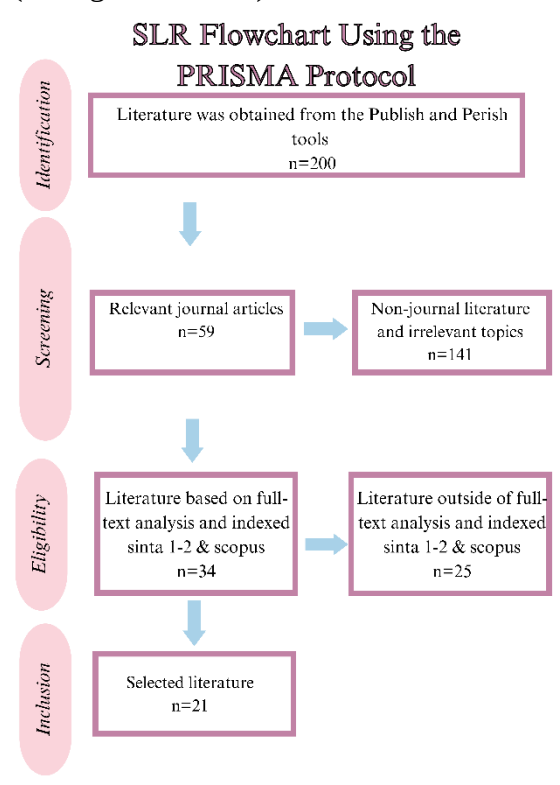


Figure 1. SLR flowchart using the PRISMA Protocol

Identification is carried out by identifying keywords and searching for terms through a database based on literature in the form of articles, books, encyclopedias, and previous research. The keywords used are ("Problem Based Learning" OR "Problem-Based Learning" OR PBL) AND ("science learning" OR "science education") AND ("elementary school" OR "primary school") AND (achievement OR "learning outcomes" OR collaboration OR "collaborative skills") AND ("elementary school" OR "primary school"). The database for this study was

obtained from Google Scholar using the Publish or Perish software (PoP). PoP was chosen because it is able to provide a wide range of literature quickly and precisely based on the selected database. The literature search was carried out on February 26, 2026 and found as many as 200 literature in the period 2016-2026.

Screening in the form of a literature screening process is carried out by referring to the inclusion criteria that have been set. The inclusion criteria focus on literature in the form of journal articles; therefore, sources such as books and conference proceedings were excluded. Each selected article was required to be relevant to the research topic, which was determined through an examination of the titles and abstracts. In addition, the selected article must be in English. At the *screening stage*, 59 articles were obtained that passed inclusion.

Eligibility is the stage of sorting out articles with exclusion criteria in the form of articles that are not *full text*, do not use English, and articles must also have scopus accreditation for international journals and SINTA 1-2 for national journals. At the *Eligibility stage*, as many as 34 articles have passed.

The final stage is inclusion, which represents the last step in the PRISMA framework. At this stage, the articles that meet all established criteria are finalized through a re-examination of the literature that has passed the inclusion requirements. There are 21 articles that go through this stage for data extraction and analysis. Data extraction is done using structured coding sheets to ensure consistency and transparency. Extracted variables include authors, year of publication, sample size, research design, and research findings.

RESULTS AND DISCUSSION

PBL Research Trends on Learning Outcomes and Collaboration in Elementary Science Learning

The results of the 21 articles analyzed show fluctuating research trends in the 2016-2026 range which can be seen in figure 2. Based on the graph shown, publications began to appear consistently in 2020 with two studies, then experienced minor fluctuations in 2021 and 2022, before increasing significantly in 2023, 2024, and reaching a peak in 2025 with eight publications. This pattern shows an accelerating trend, which indicates that PBL is increasingly gaining academic legitimacy as a relevant learning model to improve the quality of science learning at the elementary level. The absence of data in 2026 is because the current year has not yet ended when this research is written.

Substantively, the increase in the number of studies correlates with the growing need for 21st century competency development in elementary school students. Science as a subject based on scientific processes requires students not only to master concepts, but also to be able to think scientifically, solve problems, and work collaboratively (Afifah, 2021; Davidsen & Bernhard, 2026). Within the framework of social constructivism theory, effective learning occurs when students build knowledge through active interaction with the environment and peers. PBL provides this context through the presentation of authentic problems that demand group discussion, data exploration, and the development of solutions based on scientific arguments.

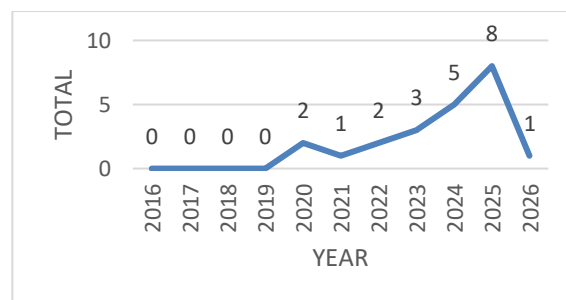


Figure 2. PBL Publication Trends on Learning Outcomes and Collaboration

The increase number of studies contributes to the advancement of education in Indonesia by supporting efforts to enhance the quality of learning. The research that has been conducted aims to improve the education system, especially related to educational practices (Coburn & Penuel, 2016). According to Susetyarini & Fauzi, (2020), research has a significant impact on education because research findings can be valid information as a basis for teachers in implementing learning practices, research results can be used as a basis for the formulation of education policies, and research can change teachers' perspectives on student development and innovative learning.

Bibliometric analysis was conducted by mapping networks of keywords related to the study focus using the VOSviewer. The visualization results in figure 3 show the interconnectedness between interconnected keywords in a conceptual network. The representation shows that there is a grouping (cluster) in the topic of PBL on learning outcomes and collaboration.

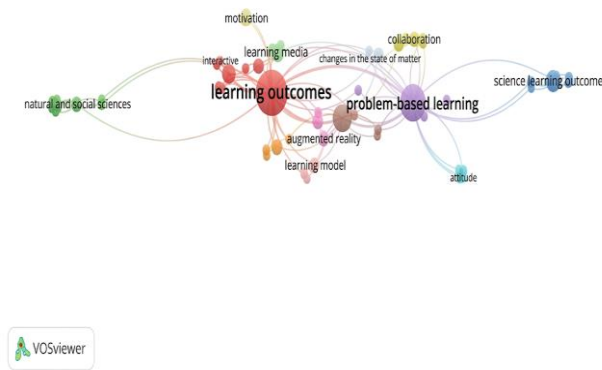


Figure 3. Keyword Network Mapping Visualization

In figure 3, it can be seen that the cluster is divided into two main keywords, namely *learning outcomes* and *problem-based learning*. This visualization of the keyword network can be a research gap. For example, *the keyword problem-based learning* is connected to *learning outcomes*. However, *learning outcomes* are not connected to *collaboration*. This gap can be the next research that examines PBL on learning outcomes and collaboration.

The density visualization can be seen in Figure 4. This visualization shows that the larger the circle and the brighter the yellow color that surrounds the keyword, the more it can be known that the keyword is often used in the research. Conversely, if the circle gets smaller and the color fades closer to the background color, then the keyword is relatively limited in use in the study (Lubis & Mulyadi, 2024; Rochman et al., 2024).

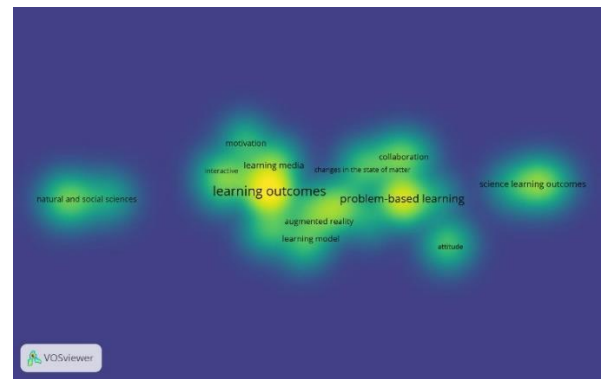


Figure 4. Density Visualization

Based in figure 4. The prominence of the keyword *learning outcomes*, which directly intersects with *problem-based learning*, indicates that the effectiveness of PBL in enhancing student learning outcomes has become a central theme in recent scholarly literature. These findings are in line with various empirical studies that show that PBL contributes significantly to improving the conceptual understanding of science in elementary schools. Research by Safitri & Hadi, (2023), shows an increase in student learning outcomes, which classically obtained a percentage of 93.6%. This increase in learning outcomes is because PBL has characteristics that use authentic problems that are open and unstructured as a trigger for learning, collaboration in small groups, the role of facilitators who guide the investigation process, iterative cycles that include problem analysis, independent learning, and reporting, as well as assessments that are in line with conceptual understanding (Funa, 2026).

In addition to *learning outcomes*, the density visualization of *collaboration* keywords is quite close to the center of the PBL cluster and *learning outcomes*. This indicates that research on student collaboration in the context of PBL is starting to develop, but the intensity is still

lower than studies on cognitive achievement. In PBL learning, collaboration is logical because it puts students in small groups to solve problems. A study by Ningsih et al., (2025) that examined *cooperative learning*, *PBL*, *discovery learning* models on communication and collaboration skills resulted in the finding that PBL proved to be the most effective model. These findings highlight the potential of innovative and interactive instructional approaches to cultivate essential social competencies required to address the challenges of globalization.

The existence of other keywords such as *augmented reality*, *learning media*, and *attitudes* that are spread more dimly shows the diversification of PBL research. Technology integration has begun to be studied to support the implementation of PBL in primary schools. However, based on density visualization, this field is still in the developing stage so that it can be a further research opportunity in synergizing PBL, digital technology, and collaboration. Overall, the results of the density visualization show that the trend of PBL research on elementary science learning from 2016-2026 is centered on learning outcomes and extends to the realm of collaboration and technology integration. This pattern reflects a paradigm shift that is not only limited to mastering concepts, but also the development of competencies in the 21st century and adjustments to technological developments.

Implications of PBL Research on Elementary Science Learning

The findings of the SLR indicate that the implementation of PBL contributes to improvements in both student learning outcomes and collaboration in elementary

science education. A summary of the analysis is presented in Table 1.

No	Journal Name (Author, Year)		Findings
1	Jurnal Pendidikan IPA Indonesia (Sajidan et al., 2022).	Pendidikan	This research resulted in the design of a Problem-Based Learning–Collaboration (PBL-C) model that integrates collaboration skill indicators
2	Jurnal Ilmiah Sekolah Dasar (Astuti et al., 2020).	Ilmiah Dasar	PBL has a positive effect on science learning outcomes among fourth-grade elementary students..
3	Jurnal Pendidikan Progresif & Fathurrahman, 2025)	Pendidikan	AR media was found to be highly feasible, with material validity reaching 88% and media validity 96%, and it effectively improved learning outcomes, as indicated by an N-Gain score of 0.74, categorized as high.
4	Jurnal Penelitian Pendidikan IPA (Wulandari & Wulandari, 2025)	Penelitian Pendidikan IPA	Smart apps creator media has been demonstrated to effectively improve the learning outcomes of fourth-grade students, indicated by significant differences (Sig. 0.00 < 0.05) and N-Gain scores in the moderate range (0.61–0.64).
5	Jurnal Pendidikan (Novitasari et al., 2023)	Penelitian Pendidikan IPA	PBL assisted by Quizizz is effective in improving science learning outcomes in grade V students compared to the STAD model.
6	Jurnal Penelitian Pendidikan IPA	Penelitian Pendidikan IPA	PBL supported by Microsoft Sway has

No	Journal Name (Author, Year)	Findings
	(Milasari et al., 2023)	been shown to be more effective than the Direct Instruction approach.
7	Jurnal Ilmiah Pendidikan dan Pembelajaran (Sulasmini et al., 2024)	Significant differences in both learning motivation and science achievement were observed between students engaged in PBL through outdoor study activities and those experiencing conventional instruction.
8	Jurnal Penelitian Pendidikan IPA (Regina & Wulandari, 2025)	PBL-based Pop Up Media is very feasible to use and effectively improves student learning outcomes.
9	Jurnal Penelitian Pendidikan IPA (Wanti & Erita, 2024)	Powtoon media developed within a PBL framework was found to be valid, feasible, and effective in improving the learning outcomes of fourth-grade students.
10	Jurnal Penelitian Pendidikan IPA (Sapira & Ansori, 2024)	Augmented reality book media integrated with PBL has been shown to be valid and effective, enhancing learning outcomes at a moderate level.
11	Jurnal Penelitian Pendidikan IPA (Safitri & Hadi, 2023)	PBL has a substantial impact on students, with learning motivation increasing by 100.00% and learning outcomes improving by 95.00%.
12	Jurnal Penelitian Pendidikan IPA (Amalia & Ratnaningrum, 2024)	PBL contributes 4% to learning outcomes, while the differentiation

No	Journal Name (Author, Year)	Findings
	2025)	approach contributes both factors positively influence learning, contributing a combined 6.3% to the science learning outcomes of fifth-grade students
13	Indonesian Journal of Educational Development (Sukmayadi, 2023)	Tri Hita Karana-oriented PBL significantly enhances both the ecological attitudes and science learning outcomes of students.
14	Indonesian Journal of Science and Mathematics Education (Praja & Andriani, 2025)	Problem-Based Learning-based interactive multimedia is very feasible (validation 93.75%–98.75%). It is also effective in enhancing learning outcomes, as indicated by a significance value of 0.000 (< 0.05) and an N-Gain of 0.735, which falls into the high category.
15	Jurnal Penelitian Pendidikan IPA (Aunurofiq & Setyasto, 2025)	Augmented Reality-assisted PBL is more effective than image-assisted PBL.
16	Jurnal Penelitian Pendidikan IPA (Fadhilah & Mulyani, 2024)	Flipbooks developed using a Problem-Based Learning approach were found to be highly feasible, with 93% media validation, 91% material validation, and a 91% positive user response. The t-test revealed a significance value of 0.01, indicating a significant difference in learning outcomes between the experimental and control groups,

No	Journal Name (Author, Year)		Findings
			demonstrating that the media effectively enhances the understanding of fifth-grade students..
17	Primary: Pendidikan Sekolah Dasar (Pradnyana et al., 2021)	Jurnal Guru	A significant difference was observed in science learning achievement between students engaged in Problem-Based Learning and those receiving conventional instruction.
18	Al-Bidayah: Pendidikan Islam (Rofiah et al., 2024)	Jurnal Dasar	Interactive media based on Articulate Storyline is very feasible to be used in learning IPAS material on Earth and Space. This media is likewise effective in enhancing learning outcomes, with an N-Gain of 0.73, categorized as high.
19	Jurnal Pendidikan (Dwiyanti & Setyasto, 2025)	Penelitian IPA	Augmented Reality-assisted PBL is more effective than image-assisted PBL.
20	Jurnal Pendidikan (Pratama & Setyasto, 2024)	Penelitian IPA	Prezi media based on PBL is very feasible to use (media validation 91.25% and material 88.90%) in science learning class IV. The results show a significance value of 0.00 and an N-Gain of 0.44, which falls within the medium category.
21	Jurnal Pendidikan MIPA (Aji et al., 2025)	Penelitian	Heyzine Flipbook media integrated with Problem-Based Learning is very feasible to use (expert validation 93.5%) and is effective in improving learning outcomes of grade V students. This is evidenced by significant

No	Journal Name (Author, Year)	Findings
		differences in pretest–posttest (0.000 < 0.05), high Effect Size values ($d = 1.767$ – 2.112), and medium category N-Gain (± 0.55).

Based on the synthesis contained in table 1, it can be seen that PBL is consistently applied independently or integrated with innovative media so that it can contribute to learning outcomes and collaboration in elementary science learning outcomes. Most experimental studies report significant differences in the experimental groups, demonstrating that PBL is not only theoretically sound but also empirically effective in elementary science education. However, the generalization of these findings is limited by the potential for publication bias, as successful studies tend to be more published than those that are not. The limited data sources and the dominance of local journals also risk limiting the diversity of school and language conditions in this analysis. This may cause the results found to reflect trends in specific journals more than a picture of overall PBL success in the field.

The integration of digital technologies such as augmented reality, articulate storyline, powtoon, quizizz, smart apps creator, prez, and heyzine shows a tendency to increase the effectiveness of PBL compared to without technology support. These findings suggest that integrating PBL with interactive media enhances the visualization of abstract scientific concepts and boosts students' cognitive engagement. This aligns with constructivist theory, which highlights the

role of meaningful learning experiences and the use of multimodal representations in developing conceptual understanding (Gunawan et al., 2025).

An interesting finding from this study is that several studies on the impact of PBL do not only affect cognitive aspects, but also affective and character aspects. For example, the Tri Hita Karana-oriented PBL model has been proven to improve ecological attitudes as well as learning outcomes (Sukmayadi, 2023). Similarly, research related to learning motivation shows that PBL has a significant impact on student motivation. This reinforces the argument that PBL has a holistic dimension relevant to 21st-century learning, especially in developing critical thinking, collaboration, and social care skills (Oscar & Ana, 2026; Sajidan et al., 2022). However, a critical issue lies in the validity of collaboration measurement across studies, as different instruments are employed, including structured observations, self-report scales, and performance-based rubrics. These variations may lead to inconsistencies in how collaboration is conceptualized and assessed, where self-report measures are more prone to subjectivity, while observational and rubric-based assessments tend to provide more objective but context-dependent evaluations. Consequently, these differences in measurement approaches should be carefully considered when interpreting the overall effectiveness of PBL on collaboration skills.

Overall, the synthesis of these findings confirms that PBL when integrated with interactive digital media is a potential approach to improve elementary science learning outcomes. However, the effectiveness of PBL largely

depends on the quality of instructional design, alignment with student characteristics, and the teacher's proficiency in facilitating the PBL process. Future research should employ more robust experimental designs, larger sample sizes, and long-term assessments to further substantiate the evidence supporting PBL in primary education.

This research provides theoretical and practical implications. Theoretically, these findings strengthen the foundation of constructivism that PBL when integrated with interactive digital media has proven effective in building conceptual understanding and affective aspects such as collaboration and increasing the motivation of elementary school students. Practically, these results imply the need to improve teachers' competence in designing technology-based PBL and support for adequate digital facilities so that the implementation is optimal and sustainable in the classroom.

CONCLUSION

A review of 21 studies confirms that PBL has a positive effect on enhancing learning outcomes. The integration of digital technology shows a tendency to increase the effectiveness of PBL compared to without technological support. These results indicate that combining PBL with interactive media enhances the visualization of abstract scientific concepts and promotes greater cognitive engagement among students. In addition, PBL does not only affect the cognitive aspect, but also the affective and character aspects. These findings provide both theoretical and practical implications. Theoretically, PBL integrated with digital media is effective in strengthening the conceptual understanding and affective

aspects of primary school students. Practically, it is necessary to improve teacher competence and support digital facilities so that the implementation is optimal and sustainable. From a policy perspective, this underscores the urgency of investing in teacher training and digital infrastructure to ensure the equitable and sustainable implementation of PBL in enhancing both learning outcomes and collaboration skills in primary education systems.

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