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Beyond the Project: A Review of Project-Based Learning (PBL) Effectiveness, Implementation Challenges & Assessment Misalignment in Secondary School Physics

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Abstract

Project-Based Learning (PBL) has gained increasing attention in secondary school Physics education for its potential to enhance students' cognitive and motivational learning outcomes. However, variations in implementation conditions and assessment practices raise questions about how its effectiveness is evaluated. This paper presents a semi-systematic literature review examining three interconnected dimensions of PBL: effectiveness, implementation challenges, and assessment alignment. Literature was identified through Google Scholar, Scopus, and Web of Science, focusing on publications from 2016 to 2026. The original screening process retained 31 articles, while the updated literature matrix comprised 38 records, including core studies and supporting literature. A critical thematic synthesis was conducted to identify recurring findings, methodological limitations, and research gaps. The findings suggest that PBL can support problem-solving, creative thinking, motivation, and student engagement. Nevertheless, differences in research designs, intervention durations, and assessment instruments limit comparisons across studies and conclusions about sustained learning outcomes. Implementation challenges involving teacher readiness, instructional time, resources, and student readiness may also influence the quality of PBL implementation. Furthermore, assessment alignment emerged as an important consideration, particularly when conventional assessments may not fully capture competencies developed through authentic project activities. However, variation in assessment instruments does not necessarily constitute evidence of misalignment. This review highlights the need for longitudinal investigations, greater integration of implementation conditions with learning outcomes, and assessment approaches aligned with intended competencies. Overall, the review provides an integrated perspective on evaluating and improving PBL in secondary school Physics education.

Keywords: Project-Based Learning, Physics Education, Secondary School, Implementation Challenges, Assessment Alignment, Semi-Systematic Literature Review

Introduction

Physics education plays an important role in developing students' conceptual understanding, scientific reasoning, and problem-solving skills. Learning Physics, however, is not only about memorising formulas or solving numerical problems. Students also need to explain concepts, make sense of physical phenomena, and apply what they learn to situations outside the classroom. Research examining physics problem-solving and students' sense-making shows why these different dimensions of learning deserve attention (Retno et al., 2019; Rosales & Sulaiman, 2016). This creates a need for teaching approaches that provide opportunities to investigate and apply Physics concepts in practical situations.

PBL is a student-centred approach that allows students to learn through investigation, collaboration, and practical activities. Instead of relying only on explanations from teachers, students are given opportunities to explore problems, develop solutions, and apply Physics concepts through projects. Previous studies have examined different outcomes associated with PBL. Retno et al. (2019) investigated physics problem-solving ability and cognitive learning outcomes, while Rosales and Sulaiman (2016) examined students' sense-making and effort. Saputri et al. (2022) focused on creative thinking through STEM-integrated PBL. These studies show that PBL may support different aspects of learning, although the outcomes measured should not be treated as equivalent. A recent systematic review specifically addressing secondary school Physics also provides a relevant synthesis of PBL theoretical foundations, design principles, and implementation strategies (Al-Kamzari & Alias, 2025). While these studies suggest that PBL can support various dimensions of student learning, understanding its effectiveness requires consideration of the practical challenges encountered during implementation and the ways learning outcomes are assessed. These factors may influence how PBL outcomes are interpreted, evaluated, and reported across different educational contexts.

A broader pedagogical perspective is provided by Ghafar (2023), who compares teacher-centred and student-centred approaches. In Physics education, Verawati and Nisrina (2025) discuss student engagement, curriculum reform, and technology integration. These sources provide educational context rather than direct evidence of PBL effectiveness in secondary school Physics. Although PBL offers educational benefits, implementing it in schools is not always straightforward. Teachers need time to plan suitable projects, prepare materials, guide students, and monitor their progress. In a case study involving five Physics teachers in Johor, Tain et al. (2023) identified challenges related to management commitment, resources, student readiness, students' time, and teachers' time. Aksela and Haatainen (2019) also reported challenges involving project organisation, technical issues, resources, and collaboration among teachers working across different educational levels. Similarly, a literature review by Syahdia et al. (2024) highlighted time constraints, inadequate infrastructure, and teacher preparation as recurring implementation concerns in secondary education. These findings suggest that PBL outcomes need to be considered alongside the conditions under which projects are carried out.

Another concern is how students' learning outcomes are assessed. PBL involves several processes, including planning, investigation, problem-solving, collaboration, and the development of a final product. However, different assessment instruments capture different aspects of these activities. In a study involving undergraduate Physics Education students, Kurniawan et al. (2024) assessed students' progress across stages of project implementation. Shpeizer (2019) also discussed the need to consider project processes, final products, and individual and group contributions when evaluating PBL in higher education. The broader literature on twenty-first-century skills similarly identifies assessment of creativity, critical thinking, communication, and collaboration as a distinct educational challenge (Thornhill-Miller et al., 2023).

Although these studies were conducted outside secondary school Physics, they illustrate why the choice of assessment instrument matters. Written tests may provide evidence of conceptual understanding, while project rubrics and process assessments may capture other competencies. The concern is not that conventional tests are ineffective, but whether the selected assessment methods reflect the intended learning outcomes.

Existing studies have examined PBL effectiveness using different research designs and assessment methods. For example, cognitive outcomes, sense-making, effort, and creative thinking represent different dimensions of learning, even when they are all reported as positive outcomes of PBL. At the same time, implementation conditions may influence what students are able to achieve during project activities. These differences make it difficult to draw one general conclusion about PBL effectiveness. They also raise questions about whether the instruments used in individual studies capture the competencies emphasised during project work. Therefore, there is a need to consider reported learning outcomes, implementation challenges, and assessment practices together rather than discussing them as separate issues.

Although previous studies and reviews have discussed various aspects of PBL, much of the literature has focused on learning outcomes, implementation processes, or assessment practices separately. The contribution of this review lies in bringing these three dimensions together within the specific context of secondary school Physics education. From a social science and educational research perspective, this integrated synthesis provides a clearer understanding of how pedagogical practices, implementation conditions, and assessment approaches collectively influence the effectiveness of PBL in school settings.

This paper presents a critical thematic synthesis of PBL in secondary school Physics education. The review focuses on three areas: the reported effectiveness of PBL in supporting students' learning, the challenges faced by teachers and students during implementation, and the alignment between intended learning outcomes and assessment practices. Studies conducted in secondary school Physics form the main evidence base, while relevant findings from Science, STEM, and higher education provide supporting perspectives. By comparing the findings, methods, and limitations of previous studies, this review aims to provide a clearer understanding of how PBL effectiveness is reported, what may influence its implementation, and how assessment approaches affect the interpretation of students' learning outcomes.

Review Approach

Literature Search and Selection

This paper adopts a semi-systematic literature review approach to examine PBL in secondary school Physics education. The review focuses on three interconnected areas: PBL effectiveness in supporting students' learning, challenges encountered during its implementation, and the alignment between intended learning outcomes and assessment practices. A semi-systematic approach was considered appropriate because previous studies have examined PBL across different educational contexts, research designs, and learning outcomes. According to Snyder (2019), this approach allows researchers to explore a broad research area, identify recurring themes, and recognise gaps in existing knowledge without necessarily following all the procedures of a systematic literature review.

The literature search was conducted between 21st and 25th of October 2026 using Google Scholar, Scopus, and Web of Science. The search terms included “secondary school”, “project-based learning”, “physics”, “STEM”, “implementation challenges”, “assessment misalignment”, and “effectiveness”. These terms were combined in different ways to identify literature relevant to the review. The search primarily focused on secondary school Physics education, while relevant studies from Science, STEM, and other educational contexts were also considered where they contributed to the three review themes. The publication period was generally limited to 2016–2026.

The initial literature search identified 80 article records. During preliminary screening, 41 records were excluded because they did not address Project-Based Learning as a teaching and learning approach. This left 39 records for further consideration. Seven duplicate records and one article published outside the selected period were subsequently removed, resulting in 31 articles in the original review selection. Following further examination of the literature and cross-checking against the original publications, the literature matrix was updated and expanded. The current master matrix contains 38 records, including studies directly related to PBL in secondary school Physics and additional literature providing supporting or contextual perspectives. These records were classified according to their relevance to the review rather than being treated as equivalent forms of evidence.

Studies directly examining PBL effectiveness, implementation challenges, or assessment practices in secondary school Physics were prioritised as core evidence. Relevant studies from broader Science, STEM, vocational education, and higher education contexts were retained as supporting evidence when their findings contributed to the interpretation of the main themes. Literature addressing general educational issues, assessment frameworks, or related pedagogical approaches was considered separately as contextual or theoretical support.

The updated literature matrix comprised 38 records, categorised into 13 core studies (34.2%), 17 supporting studies (44.7%), and eight contextual or theoretical sources (21.1%), as illustrated in Figure 2. Although supporting literature represented a larger proportion of the matrix, core studies were prioritised when drawing conclusions about PBL in secondary school Physics. Supporting and contextual literature was used to broaden the interpretation of findings and identify research gaps rather than being treated as direct evidence from the target educational context.

This distinction was important because findings from different educational contexts cannot automatically be generalised to secondary school Physics. Similarly, studies examining related approaches, such as problem-based learning, were not treated as direct evidence of project-based learning effectiveness. The inclusion and exclusion criteria are presented in Table 2.1. Figure 1 illustrates the literature identification and screening process, while Figure 2 presents the distribution of records according to their evidence categories.

Table 2.1
Inclusion and exclusion criteria for literature selection

Criterion	Inclusion criteria	Exclusion criteria
Publication year	Articles published between 2016 and 2026	Articles outside the selected period for the main research synthesis
Pedagogical approach	Studies examining PBL or providing clearly relevant supporting perspectives	Studies unrelated to PBL and without meaningful contextual relevance
Educational context	Secondary school Physics as the primary focus; relevant Science, STEM, vocational, and higher education contexts as supporting evidence	Studies without a meaningful connection to the review focus
Research focus	PBL effectiveness, implementation challenges, assessment alignment, or supporting educational concepts	Studies unrelated to the three themes and their theoretical context
Evidence relevance	Direct empirical evidence, relevant reviews, and supporting theoretical or contextual literature, classified separately	Sources whose findings cannot meaningfully inform the review
Article records	Unique articles retained according to their evidence role	Duplicate records

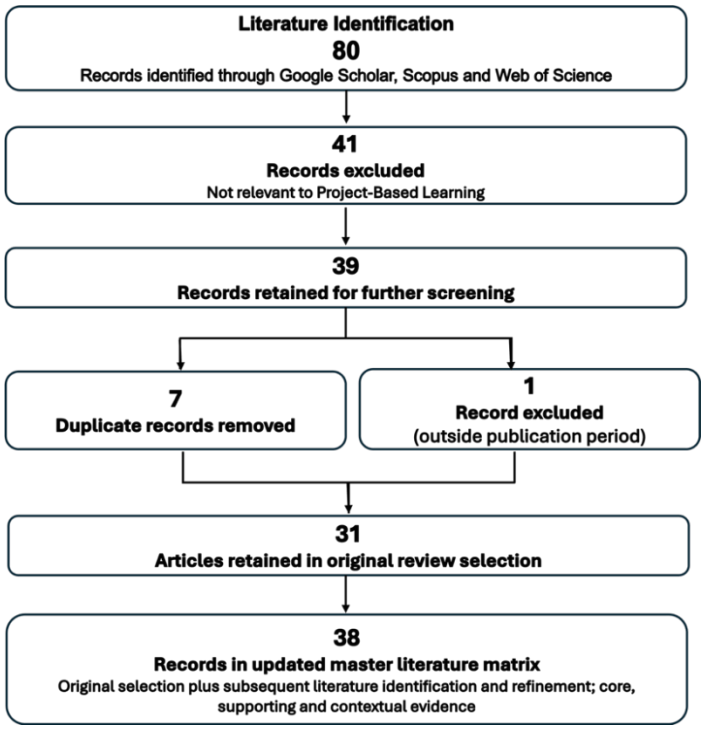


Figure 1. Literature identification, screening, and matrix development for the semi-systematic review.

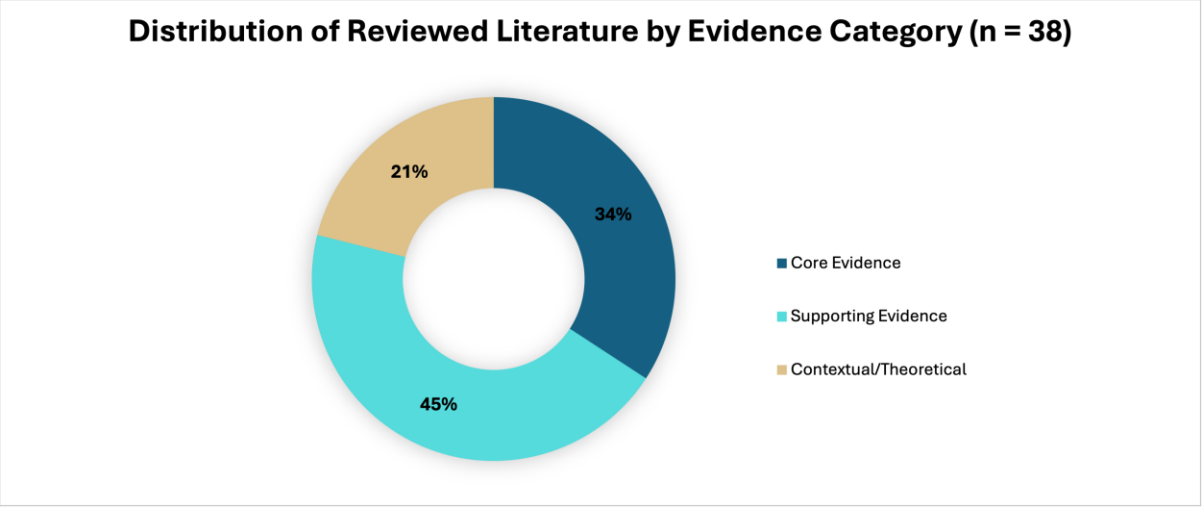


Figure 2. Pie Chart: Distribution of Literature by Evidence Category.

Literature Analysis and Thematic Synthesis

Following the literature selection process, the articles were organised into a structured literature matrix to facilitate comparison across studies. The updated matrix contains 38 records and includes information on authors, publication year, article title, educational context, research design and sample, assessment instruments, key findings, limitations, research gaps, evidence role, and verification and screening status. This structure helped distinguish direct evidence from supporting and contextual literature and identify differences in how PBL was investigated and evaluated.

The literature was analysed through critical thematic synthesis guided by three interconnected themes: PBL effectiveness, implementation challenges, and assessment alignment. Table 2.2 summarises the main themes and areas of analysis used to organise and interpret the reviewed literature.

Table 2.2
Main Themes and Areas of Analysis in the Literature Review

Main Themes	**Areas of Analysis**
Theme 1: PBL Effectiveness	• Conceptual understanding and academic achievement • Problem-solving skills • Creative thinking • Student motivation and engagement • Differences in learning outcomes and assessment measures • Methodological limitations in evaluating effectiveness
Theme 2: Implementation Challenges	• Teacher readiness and pedagogical preparation • Instructional time and project management • Availability of learning resources • Student readiness and participation • Institutional and administrative support • Potential implications for PBL implementation and learning outcomes
Theme 3: Assessment Alignment and Potential	• Alignment between intended learning outcomes, learning activities, and assessment practices

Misalignment	• Assessment of cognitive and practical competencies • Authentic project-based versus conventional assessment • Appropriateness of assessment instruments • Potential assessment misalignment and related research gaps

The thematic synthesis was conducted by comparing the reviewed studies across three interconnected areas. For PBL effectiveness, the analysis focused on the learning outcomes measured, assessment instruments employed, and methodological limitations of each study. Implementation challenges were examined by identifying recurring barriers related to teachers, students, instructional time, resources, and institutional support. The third theme examined assessment alignment to identify potential misalignment between intended learning outcomes, project-based learning activities, and assessment practices. Across all three themes, differences in educational context, research design, sample characteristics, and intervention duration were considered when interpreting the evidence. Core studies were prioritised, while supporting and contextual literature was used to broaden interpretation without generalising findings directly to secondary school Physics.

Effectiveness of Project-Based Learning in Secondary School Physics

Conceptual Understanding and Academic Performance

PBL has been increasingly explored as an instructional approach to improve students' learning outcomes in Physics education. By engaging students in authentic projects, investigation, and practical problem-solving activities, PBL provides opportunities for students to connect theoretical knowledge with real-world applications. However, the effectiveness of PBL varies depending on the learning outcomes examined, instructional design, and assessment methods employed. Several studies provide supporting evidence for the potential of PBL to improve students' cognitive learning outcomes. Related work has also examined creative problem-solving and metacognitive skills in Physics learning through STEM-oriented PBL (Fiteriani et al., 2021).

Parno et al. (2020) investigated the effectiveness of STEM-integrated PBL in developing students' problem-solving skills in electromagnetic induction. Similarly, Purwaningsih et al. (2020) examined the use of STEM-integrated project-based instructional materials and reported improvements in students' problem-solving performance. These findings suggest that PBL, particularly when integrated with STEM approaches, may support students' ability to apply Physics concepts in solving problems.

Other studies have examined different dimensions of cognitive learning. Widyasmah et al. (2020) reported improvements in students' creative thinking skills following STEM-integrated PBL activities, while Saputri et al. (2022) examined the development of creative thinking through project-based learning in the topic of momentum and impulse. Collectively, these studies indicate that PBL has the potential to support higher-order thinking skills in Physics education. Nevertheless, the reported improvements should be interpreted according to the specific learning outcomes measured. For example, improvements in problem-solving and creative thinking do not necessarily provide direct evidence of improved conceptual understanding or overall academic achievement. A broader review of project-based learning and higher-order thinking skills offers contextual support for considering these competencies

beyond a single Physics topic (Luchang & Nasri, 2023). Evidence from adjacent contexts further broadens the discussion of cognitive outcomes. Akanni (2024) examined PBL and achievement in junior secondary basic science, while Fitri et al. (2024) reviewed PBL and student creativity. Nurdiana et al. (2020) profiled creative thinking skills in junior high school science learning; this study is used as supporting context, not as evidence that PBL caused improvements in Physics learning.

Furthermore, differences in research designs, intervention durations, and assessment instruments may influence the reported effectiveness of PBL. Therefore, although the findings are generally encouraging, further evidence is needed to establish the extent to which PBL consistently improves conceptual understanding and academic performance across different secondary school Physics contexts.

Student Motivation and Engagement

In addition to cognitive learning outcomes, PBL has been associated with improvements in students' motivation, interest, and engagement in Physics learning. The use of authentic projects and collaborative activities may encourage students to participate more actively in the learning process and develop greater interest in Physics. Rosales et al. (2016) examined students' sense-making and effort in project-based Physics learning, highlighting the importance of active participation and meaningful learning experiences. Similarly, Sulaiman et al. (2023) investigated the effectiveness of an integrated STEM-PBL Physics module and reported positive outcomes related to students' interest, sense-making, and effort. These findings suggest that PBL may create learning environments that support students' motivation and engagement through practical and meaningful learning activities.

Supporting evidence from Makkonen et al. (2021) also indicates that project-based activities may encourage engagement among upper-secondary Physics students by providing opportunities for autonomy and active participation. However, the educational context and characteristics of the participants should be considered when interpreting these findings. Although improvements in motivation and engagement are important, they should not automatically be interpreted as evidence of improved academic performance. Studies examining students' interest, effort, or learning experiences measure different outcomes from those assessing conceptual knowledge or problem-solving performance. Consequently, evaluating PBL effectiveness requires consideration of both students' learning experiences and their demonstrated cognitive outcomes. Research examining integrated STEM project-based Physics learning from neuroscience perspectives offers an additional interpretive lens, although it should not be treated as equivalent to a direct classroom effectiveness evaluation (Uden et al., 2023).

Research on engagement and motivation in other educational settings offers additional supporting perspectives. Nugroho et al. (2025) examined student engagement in PBL within the Merdeka Curriculum, while Zhang and Lin (2026) studied PBL and learning motivation in animation programmes. Their different educational contexts limit direct generalisation to secondary school Physics.

Critical Synthesis of PBL Effectiveness

Overall, the reviewed literature provides evidence that PBL has the potential to support several dimensions of Physics learning, particularly problem-solving, creative thinking, motivation, and engagement (Parno et al., 2020; Purwaningsih et al., 2020; Widyasmah et al., 2020; Sulaiman et al., 2023). However, the findings also indicate that PBL effectiveness cannot be interpreted as a single or uniform outcome. One important issue is the variation in learning outcomes and assessment instruments across studies. While some studies focus on problem-solving and creative thinking, others examine students' motivation, interest, and engagement. These outcomes represent different dimensions of learning and should not be treated as interchangeable indicators of PBL effectiveness. Crawford et al. (2024) examined students' self-reported and actual learning in a PBL setting, offering a relevant supporting perspective on why outcome measures should be interpreted separately.

Furthermore, methodological differences, including intervention duration, sample characteristics, research design, and instructional support, may influence the reported results. In particular, findings from short-term interventions or studies without comparison groups may provide limited evidence regarding the long-term effectiveness of PBL. From a semi-systematic review perspective, these differences highlight the importance of critically synthesising the evidence rather than relying solely on positive findings from individual studies. Although PBL demonstrates potential to enhance Physics learning, its effectiveness may depend on how project activities are designed, implemented, and assessed.

Therefore, understanding PBL effectiveness requires further consideration of the implementation challenges experienced by teachers and students, as well as the alignment between intended learning outcomes and assessment practices. These issues are examined in the following sections.

Implementation Challenges of Project-Based Learning in Secondary School Physics

Teacher Readiness and Time Constraints

Despite the potential benefits of Project-Based Learning (PBL), its implementation in secondary school Physics education presents several challenges, particularly concerning teacher readiness and time constraints. Unlike conventional teaching approaches, PBL requires teachers to design meaningful projects, facilitate student investigations, monitor learning progress, and assess multiple learning outcomes. These responsibilities may increase instructional demands, especially when teachers have limited experience or professional support in implementing PBL. Research from other educational contexts has also considered collaboration challenges from students' perspectives, which may help contextualise the coordination demands of project work (Hussein, 2021).

Aksela and Haatainen (2019) identified several challenges associated with the implementation of PBL, including the demands of project planning, time management, and the support required for effective implementation. Similarly, Tain et al. (2023), in a qualitative study involving Physics teachers in Johor, Malaysia, identified challenges related to teacher time, student time, resources, and management commitment. These findings suggest that successful PBL implementation depends not only on teachers' willingness to adopt the approach but also on the conditions that support its practical application. A review focused

on secondary school contexts likewise discusses implementation barriers across countries, providing supporting rather than Physics-specific evidence (Syahdia et al., 2024).

Time constraints are particularly relevant in secondary school Physics, where teachers must balance project activities with curriculum requirements and examination preparation. Curriculum transformation also provides a broader context for understanding the challenges teachers face when adapting instructional practices to changing educational expectations (Dariyono & Rusman, 2023). Project planning, experimentation, group discussions, and presentations may require more instructional time than conventional lessons. Consequently, teachers may experience difficulties completing project activities while ensuring sufficient coverage of prescribed Physics content. However, these challenges should not be interpreted as evidence that PBL is inherently ineffective. Rather, they highlight the importance of teacher preparation, instructional planning, and institutional support in determining how effectively PBL can be implemented.

Resource Availability and Student Readiness

Resource availability represents another challenge in implementing PBL, particularly when Physics projects involve experimental equipment, materials, technology, and suitable learning spaces. Limited access to these resources may restrict the types of projects teachers can design and the extent to which students can engage in practical investigations. Tain et al. (2023) identified resource limitations as one of the challenges experienced by Physics teachers in implementing PBL. Such limitations may require teachers to modify project activities or rely on available materials, potentially affecting the learning experiences intended through the approach. Student readiness is equally important. PBL requires students to participate actively in planning, investigation, collaboration, and problem-solving. However, students may differ in their prior knowledge, confidence, learning independence, and ability to manage project responsibilities. Tain et al. (2023) also identified student readiness and time-related challenges, suggesting that students may require additional guidance when adapting to project-based activities.

These challenges indicate that providing students with authentic projects alone may not be sufficient to ensure effective learning. Appropriate scaffolding, clear instructions, manageable project tasks, and continuous teacher guidance may be necessary to support students throughout the learning process. Nevertheless, the extent to which resource limitations and student readiness directly affect Physics achievement remains insufficiently established by the implementation-focused evidence discussed here. Further investigation is needed to determine how these factors influence specific learning outcomes. The development of an integrated STEM-PBL Physics module for classical mechanics provides a related example of instructional design work, although module development alone does not demonstrate learning effectiveness (Rosales & Sulaiman, 2020).

Critical Synthesis of Implementation Challenges

The reviewed literature indicates that PBL implementation challenges involve interconnected factors rather than isolated classroom difficulties. Teacher readiness, instructional time, resource availability, student readiness, and institutional support may collectively influence the quality and consistency of project-based activities (Aksela & Haatainen, 2019; Tain et al., 2023). Related discussions of PBL implementation appear in

Malaysian vocational education (Adnan & Abdul Rahman, 2024) and higher education (Evenddy et al., 2023). Nguyen et al. (2023) also provide a bibliometric perspective on STEM education implementation. These sources broaden the contextual discussion but are not treated as direct empirical evidence about secondary school Physics teachers.

A key issue emerging from these findings is the relationship between implementation conditions and reported PBL effectiveness. While studies examining learning outcomes frequently report improvements in selected competencies, implementation-focused studies highlight the practical demands of delivering project activities. These two strands of evidence suggest that positive learning outcomes cannot be considered independently of the instructional conditions under which PBL is implemented.

However, the available evidence does not consistently establish direct relationships between specific implementation challenges and measurable changes in students' Physics performance. Studies identifying teachers' experiences and perceptions provide valuable insights into implementation barriers, but they do not necessarily demonstrate the extent to which those barriers affect conceptual understanding, problem-solving, or academic achievement.

This distinction highlights an important research gap. Future studies should examine implementation conditions alongside student learning outcomes to determine which challenges have the greatest influence on PBL effectiveness and how appropriate support strategies may address them. Furthermore, implementation challenges may have implications for assessment practices. When teachers face limited instructional time, resources, or assessment support, evaluating students' project processes and learning outcomes may become more difficult. This raises questions about whether existing assessment practices adequately capture the competencies developed through PBL, particularly in examination-oriented secondary school Physics contexts. The issue of assessment alignment is examined in the following section.

Assessment Misalignment in Project-Based Learning in Secondary School Physics

Authentic Learning Outcomes and Standardised Assessment

PBL emphasises authentic learning experiences that encourage students to apply knowledge, investigate problems, collaborate, and develop solutions through meaningful projects. In secondary school Physics, these activities may support a range of learning outcomes, including conceptual understanding, problem-solving, creative thinking, and scientific reasoning. However, assessing these outcomes presents challenges when assessment practices focus primarily on written examinations and individual performance.

A central concern is the potential misalignment between the competencies developed through PBL and the learning outcomes captured by conventional assessment methods. While written tests may provide useful evidence of students' conceptual knowledge and problem-solving performance, they may not fully capture the processes involved in project planning, investigation, collaboration, and practical application. Zhao et al. (2023) examined the alignment between teaching, learning, and assessment in the implementation of PBL under curriculum standards. Their study provides a relevant perspective on the importance of ensuring that assessment practices correspond with intended learning outcomes and

classroom activities. Although the study was not limited to secondary school Physics, its focus on instructional alignment offers a useful framework for examining assessment practices in PBL. Nevertheless, the existence of different assessment approaches does not necessarily indicate assessment misalignment. Misalignment occurs when the assessment methods employed do not adequately correspond with the intended learning outcomes or learning activities. Therefore, the relationship between authentic PBL experiences and standardised assessment should be examined in terms of what students are expected to learn and what the assessment instruments are designed to measure.

Challenges in Assessing PBL Learning Outcomes

Assessing the effectiveness of PBL requires consideration of both the learning process and the outcomes demonstrated by students. Unlike conventional classroom activities, project-based tasks may involve multiple competencies that cannot always be represented adequately through a single assessment instrument. The reviewed studies demonstrate variation in the outcomes and measures used to evaluate PBL effectiveness. For example, Parno et al. (2020) and Purwaningsih et al. (2020) examined problem-solving performance, while Widyasmah et al. (2020) investigated creative thinking skills. In contrast, Sulaiman et al. (2023) focused on students' interest, sense-making, and effort. These studies provide evidence of different dimensions of PBL effectiveness, but their findings are not directly interchangeable. Assessment research in undergraduate Physics Education has also examined project implementation stages as a basis for evaluating project-based learning processes (Kurniawan et al., 2024).

Such variation highlights the importance of selecting assessment instruments that correspond with the intended learning outcomes. Problem-solving tests may be appropriate for evaluating students' application of Physics knowledge, while questionnaires can provide information about motivation and engagement. However, neither approach necessarily captures the full range of competencies involved in project-based activities. Assessing collaborative processes, practical investigations, and students' contributions to group projects may require additional approaches, such as observation, performance-based tasks, reflective activities, or assessment rubrics. These approaches could complement written tests by providing evidence of learning processes that may otherwise remain less visible. However, the use of multiple assessment instruments does not automatically ensure alignment. Their effectiveness depends on whether the assessment criteria are clearly connected to the intended learning outcomes and whether the resulting evidence is interpreted appropriately. Broader discussions of PBL in higher education likewise address the assessment of project processes and outputs, although their applicability to secondary Physics requires careful consideration (Shpeizer, 2019).

Assessment-related supporting literature addresses complementary issues. Marhaeni et al. (2020) examined assessment literacy among elementary teachers, Pesigan (2025) considered PBL as an assessment tool for students with special needs, and Sumo et al. (2024) examined the validity and practicality of a scientific-creativity PBL model among Physics education undergraduates. These different contexts illustrate assessment considerations without directly establishing misalignment in secondary school Physics.

Critical Synthesis of Assessment Misalignment

The reviewed literature reveals an important distinction between evidence of PBL effectiveness and evidence of assessment alignment. Studies reporting improvements in problem-solving, creative thinking, or motivation demonstrate the potential benefits of PBL within the outcomes measured. However, these findings do not necessarily establish whether the assessment practices used adequately represent the broader competencies intended through project-based learning. For instance, studies by Parno et al. (2020), Purwaningsih et al. (2020), and Widyasmah et al. (2020) provide supporting evidence of improvements in selected cognitive competencies. Nevertheless, differences in the competencies assessed and the instruments employed make it difficult to compare the overall effectiveness of PBL across studies. These differences indicate limitations in cross-study comparison rather than direct evidence of assessment misalignment.

Zhao et al. (2023) offers a complementary perspective by examining teaching–learning–assessment alignment directly. This highlights the need to consider not only whether students demonstrate improvements, but also whether the assessment methods reflect the intended learning outcomes and the learning experiences provided through PBL. From a critical synthesis perspective, assessment misalignment emerges as an important issue requiring further investigation in secondary school Physics education. In particular, there is a need to examine how authentic project-based competencies can be assessed alongside curriculum-based academic requirements without overlooking either dimension of learning.

Future research should therefore investigate the alignment between PBL objectives, classroom activities, and assessment practices. Greater attention to assessment design, clear performance criteria, and the combination of appropriate assessment methods may provide a more comprehensive evaluation of students' learning. Overall, the literature suggests that understanding PBL effectiveness requires more than identifying positive learning outcomes. It also requires examining whether the assessment practices employed are sufficiently aligned with the competencies that PBL is intended to develop. This issue is particularly relevant to secondary school Physics, where authentic learning experiences must operate within established curriculum and examination requirements.

Critical Discussion and Research Gaps

The reviewed literature indicates that PBL has the potential to support students' problem-solving, creative thinking, motivation, and engagement in Physics education. However, the findings also reveal important limitations concerning the consistency of learning outcomes, implementation conditions, and assessment practices. These issues suggest that PBL effectiveness should not be evaluated independently of how project activities are implemented and how students' learning is assessed.

Limited Evidence of Sustained Learning Outcomes

Although several studies report positive outcomes following PBL implementation, differences in intervention duration, research design, and assessment instruments limit the extent to which findings can be compared across educational contexts. For example, Parno et al. (2020) and Purwaningsih et al. (2020) provide supporting evidence concerning problem-

solving skills, while Widyasmah et al. (2020) examines creative thinking. Sulaiman et al. (2023), meanwhile, focuses on students' interest, sense-making, and effort.

These findings demonstrate the potential of PBL across different learning dimensions, but they do not establish whether improvements are consistently sustained over time. In particular, evidence of immediate post-intervention gains should be distinguished from evidence of long-term knowledge retention or transfer to unfamiliar Physics problems. Therefore, further research is needed to examine whether the learning benefits associated with PBL are maintained beyond the intervention period, particularly in relation to conceptual understanding and the application of Physics knowledge.

Limited Integration of Implementation Conditions and Learning Outcomes

A second research gap concerns the relationship between implementation challenges and students' learning outcomes. Studies examining PBL effectiveness commonly focus on measurable improvements in selected competencies, whereas implementation-focused studies investigate the practical difficulties experienced by teachers and students. For example, Aksela and Haatainen (2019) and Tain et al. (2023) identify challenges related to time, resources, teacher support, and student readiness. However, these findings do not necessarily establish how individual implementation barriers influence students' conceptual understanding, problem-solving performance, or academic achievement.

This separation between effectiveness research and implementation research limits understanding of the conditions under which PBL is most successful. Future studies should therefore investigate learning outcomes alongside implementation factors, including instructional support, resource availability, teacher readiness, and students' prior learning experiences. Such investigations could provide a clearer explanation of why PBL produces different outcomes across educational settings and help identify practical strategies for improving its implementation in secondary school Physics.

Insufficient Examination of Assessment Alignment

A third research gap concerns the alignment between intended learning outcomes, project-based learning activities, and assessment practices. The reviewed studies employ different instruments to measure problem-solving, creative thinking, motivation, and engagement. Although these instruments provide evidence of particular learning outcomes, their variation makes it difficult to compare the broader effectiveness of PBL across studies. Importantly, differences in assessment instruments should not be interpreted as direct evidence of assessment misalignment. Rather, they highlight the need to examine whether the instruments used are appropriate for the competencies that PBL is intended to develop.

Zhao et al. (2023) provides a relevant perspective by examining teaching–learning–assessment alignment in project-based learning. However, further investigation is needed to establish how such alignment is addressed specifically in secondary school Physics, particularly where authentic project activities must operate alongside curriculum-based and examination requirements. Future research should therefore examine the relationship between project objectives, classroom learning experiences, and assessment criteria. Combining appropriately designed cognitive assessments with performance-based evidence

may offer a more comprehensive understanding of students' learning without assuming that any single instrument can capture all intended competencies.

Integrating Effectiveness, Implementation, and Assessment

Collectively, the three research gaps highlight the need for a more integrated understanding of PBL in secondary school Physics. Evidence of improved learning outcomes is valuable, but it does not fully explain the conditions responsible for those improvements or whether the assessments employed adequately represent the intended learning objectives. Similarly, identifying implementation barriers provides important contextual information, but does not establish their effects on student achievement without corresponding outcome measures. Assessment alignment adds a further dimension by examining whether the evidence collected accurately reflects the competencies developed through project-based activities.

The thematic synthesis revealed an uneven distribution of direct evidence across the three review themes. While several studies examined PBL effectiveness in secondary school Physics, comparatively fewer directly investigated implementation challenges or assessment alignment. This gap highlights the need for future research to examine learning outcomes, implementation conditions, and assessment practices as interconnected dimensions, providing a more comprehensive basis for evaluating PBL in secondary school Physics education.

Future Research Directions

The findings of this semi-systematic literature review highlight several directions for future research on PBL in secondary school Physics education. Although previous studies have demonstrated the potential of PBL to support selected cognitive and motivational outcomes, further investigation is needed to strengthen the evidence concerning sustained learning, implementation conditions, and assessment alignment.

Longitudinal Evaluation of PBL Effectiveness

Future research should investigate the long-term effectiveness of PBL beyond immediate post-intervention outcomes. While existing studies provide evidence of improvements in problem-solving, creative thinking, and student engagement (Parno et al., 2020; Widyasmah et al., 2020; Sulaiman et al., 2023), further investigation is needed to determine whether these benefits are sustained over time. Longitudinal or delayed post-test designs could provide stronger evidence of knowledge retention, conceptual understanding, and students' ability to transfer Physics knowledge to unfamiliar situations. Such approaches may help distinguish short-term improvements from sustained learning outcomes.

Examining Implementation Conditions and Learning Outcomes

Future studies should examine the relationship between PBL implementation conditions and students' learning outcomes. Challenges involving teacher readiness, instructional time, resource availability, and student readiness have been identified in previous research (Aksela & Haatainen, 2019; Tain et al., 2023). However, further evidence is needed to determine how these factors influence PBL effectiveness. Research combining classroom observations, teacher perspectives, and student performance measures could provide a more comprehensive understanding of the conditions that support or constrain PBL

implementation. Particular attention should be given to practical strategies that enable teachers to implement meaningful projects while meeting secondary school Physics curriculum requirements.

Strengthening Assessment Alignment in PBL

Further research is also needed to examine the alignment between intended learning outcomes, project-based activities, and assessment practices. Zhao et al. (2023) highlights the importance of teaching–learning–assessment alignment in PBL, while studies examining different learning competencies demonstrate the diversity of assessment approaches used to evaluate its effectiveness. Future studies should investigate how written assessments, performance-based tasks, observation, and assessment rubrics can be appropriately combined to evaluate both conceptual knowledge and competencies developed through project activities. Rather than assuming that multiple assessment methods automatically ensure alignment, researchers should examine whether each instrument measures the intended learning outcomes.

In examination-oriented secondary school Physics contexts, particular attention should be given to balancing authentic project-based learning with curriculum-based assessment requirements. Such research could inform the development of assessment practices that recognise both students' conceptual understanding and their ability to apply Physics knowledge in meaningful situations. Overall, future research should adopt a more integrated approach to evaluating PBL by considering learning outcomes, implementation conditions, and assessment alignment together. This may provide a stronger evidence base for understanding when, how, and under what conditions PBL contributes effectively to secondary school Physics education.

Conclusion

This semi-systematic literature review examined the effectiveness, implementation challenges, and assessment misalignment associated with PBL in secondary school Physics education. Through critical thematic synthesis, the review identified the potential of PBL to support students' problem-solving, creative thinking, motivation, and engagement. However, the reported benefits vary according to the learning outcomes measured, instructional approaches, and research designs employed. The review also highlighted implementation challenges involving teacher readiness, instructional time, resource availability, and student readiness. These factors may influence the quality and consistency of PBL implementation, suggesting that its effectiveness should be considered in relation to the conditions under which project activities are conducted.

Furthermore, assessment alignment emerged as an important consideration in evaluating PBL effectiveness. Although previous studies have employed various instruments to measure students' learning outcomes, differences in assessment approaches do not necessarily demonstrate misalignment. Instead, they highlight the need to examine whether assessment practices adequately reflect the intended learning outcomes and competencies developed through project-based activities. Overall, this review contributes to the literature by integrating three interconnected dimensions of PBL: effectiveness, implementation conditions, and assessment alignment. It highlights the need for future research that examines sustained learning outcomes, investigates the relationship between

implementation challenges and student performance, and strengthens alignment between project-based activities and assessment practices. Addressing these issues may provide a more comprehensive understanding of PBL and support its effective implementation in secondary school Physics education.

Declaration of Generative AI Use

Generative AI (ChatGPT, OpenAI) was used to assist with preliminary literature screening, thematic classification, literature matrix development, and language refinement. The author independently identified and collected the literature, cross-checked article titles and sources against the original publications, and conducted the critical synthesis with the assistance of AI. The author retained full responsibility for the final selection, interpretation, critical evaluation, and presentation of the reviewed evidence.

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