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# The Effectiveness of Project-Based Learning in Enhancing Conceptual Understanding and Critical Thinking Skills: A Literature Analysis

**Subuh Triyasa[1*], Yoto[2], Nunung Nurjanah[3]**
[1,2,3]Vocational Education Study Program, Graduate School, Universitas Negeri Malang
Correspondence Email: subuh.triyasa.2405518@students.um.ac.id

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**Abstract:**

The demands of the Industrial Revolution 4.0 require graduates of Vocational High Schools (*Sekolah Menengah Kejuruan*/SMK) to possess strong conceptual understanding and well-developed critical thinking skills in order to address complex workplace problems. However, instructional practices in vocational education remain largely dominated by conventional approaches that are insufficient to foster higher-order thinking skills. This study aims to examine the effectiveness of Project-Based Learning (PjBL) in enhancing these two competencies through a systematic literature analysis of peer-reviewed scientific articles published between 2015 and 2024, guided by the PRISMA flowchart. The findings indicate that PjBL consistently contributes to improved learning outcomes; nevertheless, most existing studies tend to investigate conceptual understanding and critical thinking as separate constructs. The effectiveness of PjBL implementation is significantly influenced by external factors, including teacher readiness, infrastructure availability, and effective time management. This synthesis highlights the urgent need to integrate conceptual reinforcement and critical reasoning within project design in vocational high schools to better prepare competent graduates. Future research is recommended to employ mixed-methods approaches to examine the simultaneous relationship between these two competencies, thereby strengthening the empirical foundation of vocational education.

**Abstrak:**

Tuntutan Revolusi Industri 4.0 mengharuskan lulusan Sekolah Menengah Kejuruan (SMK) memiliki pemahaman konseptual yang kuat serta keterampilan berpikir kritis yang baik agar mampu menyelesaikan permasalahan kompleks di dunia kerja. Namun, praktik pembelajaran di pendidikan vokasi masih didominasi oleh pendekatan konvensional yang belum mampu secara optimal mengembangkan keterampilan berpikir tingkat tinggi. Penelitian ini bertujuan untuk mengkaji efektivitas penerapan Project-Based Learning (PjBL) dalam meningkatkan kedua kompetensi tersebut melalui analisis literatur sistematis terhadap artikel ilmiah bereputasi yang dipublikasikan pada periode 2015–2024 dengan menggunakan alur PRISMA. Hasil analisis menunjukkan bahwa PjBL secara konsisten berkontribusi terhadap peningkatan hasil belajar; namun demikian, sebagian besar penelitian masih mengkaji pemahaman konseptual dan keterampilan berpikir kritis secara terpisah. Keberhasilan implementasi PjBL sangat dipengaruhi oleh faktor eksternal, seperti kesiapan guru, ketersediaan infrastruktur, serta pengelolaan waktu yang efektif. Sintesis ini menegaskan urgensi integrasi penguatan konsep dan penalaran kritis dalam perancangan proyek di SMK guna menghasilkan lulusan yang kompeten. Penelitian selanjutnya direkomendasikan

untuk menggunakan desain metode campuran (mixed methods) guna menguji hubungan simultan antara kedua variabel tersebut, sehingga dapat memperkuat landasan empiris pendidikan vokasi.

**Keywords:**
Project-Based Learning, Conceptual Understanding, Critical Thinking, Vocational Education, Literature Study Body Text.

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## Introduction

Vocational education plays a pivotal role in preparing competent, adaptive, and competitive human resources in the era of the Fourth Industrial Revolution. Graduates of Vocational High Schools (*Sekolah Menengah Kejuruan*/SMK) are expected not only to master technical skills but also to possess strong critical thinking abilities and robust conceptual understanding in order to address complex and dynamic problems in the workplace. However, instructional practices in many SMKs remain predominantly characterized by conventional, teacher-centered approaches that emphasize rote learning. Such practices tend to overlook the development of higher-order thinking skills (HOTS), which are essential competencies for 21st-century learners (Brookhart, 2019).

In response to this challenge, Project-Based Learning (PjBL) has emerged as an innovative pedagogical approach that places students at the center of the learning process. Through the implementation of authentic and contextually relevant projects, PjBL encourages learners to explore concepts, design solutions, execute tasks, and reflect on their learning outcomes. This approach facilitates the integration of the cognitive, psychomotor, and affective learning domains while fostering student engagement, collaboration, and motivation. Theoretically, PjBL is grounded in constructivist learning theory, which posits that knowledge is actively constructed through experience and reflection (Thomas, 2020). Furthermore, it aligns with Dewey's theory of progressive education, which emphasizes meaningful learning through inquiry and problem-solving. Within vocational education contexts, PjBL is particularly relevant because it bridges the gap between theory and practice, as well as between conceptual understanding and practical application, both of which are central to vocational learning (Mahanal, Zubaidah, Bahri, & Dinnurriya, 2019).

This study is necessary due to the persistent gap between the demands of 21st-century competencies and the reality of instructional practices in Vocational High Schools

(SMK), which continue to be dominated by conventional methods. Accordingly, this research aims to provide both theoretical and practical foundations for the development of a more adaptive and contextually responsive vocational education curriculum. Through a systematic literature analysis, this study seeks to demonstrate how Project-Based Learning can be optimized to integrate conceptual reinforcement and critical thinking skill development, thereby contributing to the preparation of competent and competitive SMK graduates in the era of the Industrial Revolution 4.0.

Conceptual understanding constitutes a fundamental component of vocational competence, as it enables students to link theoretical principles with real-world phenomena and apply this knowledge across diverse contexts. Empirical evidence indicates that Project-Based Learning (PjBL) effectively enhances conceptual understanding by engaging students in authentic and meaningful learning experiences. Rizani, Taufiqulloh, and Sudibyo (2022) reported that PjBL-based instructional modules significantly improved both conceptual understanding and critical thinking among vocational students. Similarly, Andriyanto and Rahdiyanta (2025) found that project-oriented learning activities facilitate the internalization of theoretical knowledge through hands-on problem-solving processes. In the context of automotive education, Sudarma and Nuryanto (2025) demonstrated that the implementation of PjBL strengthened students' mastery of 4C skills, critical thinking, creativity, communication, and collaboration, while simultaneously promoting deeper technical conceptualization. Likewise, Zhang, Guan, and Hu (2024) revealed that the application of blended PjBL in construction cost estimation courses enhanced students' conceptual understanding through contextualized problem-solving tasks. These findings are consistent with research in STEM education, which emphasizes that the integration of PjBL and STEM elements fosters conceptual learning through experimentation and authentic assessment (Wijayanti, Mulyani, & Rahmawati, 2021).

Critical thinking, meanwhile, has been widely recognized as an essential competency for 21st-century vocational graduates. Facione (2020) defines critical thinking as a reflective cognitive process involving analysis, inference, and the evaluation of evidence prior to decision-making. Within vocational education, critical thinking enables learners to identify technical problems, assess alternative solutions, and implement appropriate corrective actions. A substantial body of research has confirmed the effectiveness of PjBL in enhancing critical thinking skills. Prasetyo and Suparman (2022) reported a 47.05% increase in students' critical thinking abilities following the implementation of PjBL in the Building Construction and Utilities subject. Furthermore, studies by Sari and Wicaksono (2024) and Dewi, Wirawan, and Suryani (2021) demonstrated that the integration of PjBL with design thinking and e-learning strategies promotes analytical and reflective thinking through collaborative learning and digital exploration. Collectively, these studies suggest that PjBL not only strengthens technical competence but also cultivates analytical and reflective dispositions that are crucial for workplace readiness.

Despite these demonstrated benefits, the existing literature reveals several notable research gaps. First, the majority of studies investigate conceptual understanding and

critical thinking as separate constructs, despite evidence that these competencies are interrelated and mutually reinforcing (Az-Zahra, Rusdi, & Ristanto, 2021). Second, there is a paucity of comparative research examining different PjBL models, such as blended, interdisciplinary, or community-based projects, and their simultaneous effects on conceptual understanding and critical thinking skills. Third, contextual and external factors, including teacher readiness, infrastructure availability, project duration, and school culture, remain underexplored, even though these variables significantly influence the effectiveness of PjBL implementation (Rahmadani, Wahyuni, & Sugiarto, 2020). In light of these research gaps, this study aims to conduct a systematic literature analysis on the effectiveness of Project-Based Learning (PjBL) in enhancing conceptual understanding and critical thinking skills among vocational students. This review seeks to provide a comprehensive perspective on how, under what conditions, and to what extent PjBL can optimize these two critical dimensions of learning within vocational education in the era of Industry 4.0.

The central problem addressed in this study concerns the limited understanding of how the Project-Based Learning (PjBL) model simultaneously supports the development of conceptual understanding and critical thinking skills among students in Vocational High Schools (*Sekolah Menengah Kejuruan*/SMK). The urgency of this research is further underscored by the escalating challenges of the Industrial Revolution 4.0 and the increasing complexity of learning demands, which require SMK graduates not only to possess strong conceptual foundations but also to demonstrate advanced critical thinking and problem-solving abilities. Accordingly, this study aims to synthesize findings from the existing literature on the effectiveness of PjBL in improving conceptual understanding and critical thinking skills among SMK students, thereby contributing to the preparation of graduates who are better equipped to meet future challenges, particularly in the workplace.

## Research Method

### Research Design

This study employed a systematic literature review using a descriptive qualitative approach to identify, evaluate, and synthesize empirical research on the effectiveness of Project-Based Learning (PjBL) in enhancing students' conceptual understanding and critical thinking skills within vocational education contexts.

### Data Sources

The data for this study were obtained from accredited national journals indexed in SINTA (levels 1–4) and reputable international journals published between 2015 and 2024. The literature search was conducted using the Garuda, Google Scholar, Directory of Open Access Journals (DOAJ), and SpringerLink databases. The search strategy utilized the following keywords: "Project-Based Learning," "vocational education," "critical thinking," and "conceptual understanding." The inclusion criteria were as follows: 1) Studies investigating the implementation of Project-Based Learning (PjBL) at the Vocational High

School (*Sekolah Menengah Kejuruan*/SMK) level or equivalent secondary vocational institutions; 2) empirical research analyzing variables related to conceptual understanding and/or critical thinking skills; 3) studies employing quantitative, qualitative, or mixed-methods research designs. The exclusion criteria comprised conceptual or theoretical papers without empirical evidence, non-scientific reports or unpublished theses, and publications that had not undergone a peer-review process.

**Analysis Procedure**

The analysis procedure in this study followed four main stages. First, the identification and selection of relevant literature were conducted by retrieving articles using the keywords "Project-Based Learning," "critical thinking," "conceptual understanding," "vocational education," and "SMK" across multiple academic databases. An initial screening was carried out based on article titles and abstracts to determine their relevance to the research focus. Second, a quality evaluation was performed to assess each selected article in terms of methodological rigor, clarity of research design, validity of findings, and relevance to the objectives of the study. Third, data extracted from the selected studies were systematically coded and categorized into four thematic dimensions: (a) the implementation of Project-Based Learning, (b) conceptual understanding, (c) critical thinking skills, and (d) supporting and inhibiting factors influencing the effectiveness of PjBL. Finally, a thematic synthesis was undertaken to identify patterns, similarities, and variations across the reviewed studies, which subsequently informed the development of theoretical insights and practical implications..

**Literature Selection Process**

The analysis procedure in this systematic literature review was conducted through four main stages. First, the identification and selection of relevant literature were carried out by retrieving articles using the keywords "Project-Based Learning," "critical thinking," "conceptual understanding," "vocational education," and "SMK" across multiple academic databases. An initial screening based on article titles and abstracts was performed to assess relevance to the research focus. Second, a quality evaluation stage was undertaken to assess each selected article in terms of methodological rigor, clarity of research design, validity of findings, and relevance to the objectives of the present study. Only studies that met acceptable quality standards were retained for further analysis. Third, the data extracted from the selected studies were systematically coded and categorized into four thematic dimensions: (a) the implementation of Project-Based Learning (PjBL), (b) conceptual understanding, (c) critical thinking skills, and (d) supporting and inhibiting factors influencing the effectiveness of PjBL. Finally, a thematic synthesis was conducted to identify patterns, similarities, and variations across the studies, which formed the basis for drawing theoretical and practical conclusions.

The literature selection process followed a simplified adaptation of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework (Page, McKenzie, Bossuyt, & Boutron, 2021). From an initial pool of 40 identified articles, 25 studies were retained after title and abstract screening. Subsequent full-text

assessment resulted in 12 articles meeting the predefined eligibility criteria, and ultimately, 5 high-quality studies were included in the final thematic synthesis. The adapted PRISMA-based literature selection process is presented in Table 1.

**Table 1.** Literature Selection Steps (Adapted from PRISMA 2020)

| Selection Stage | Description of Activities | Number of Article |
|---|---|---|
| Identification | Literature search using the keywords "Project-Based Learning", "critical thinking", "conceptual understanding", "vocational education", and "SMK" in databases: Google Scholar, DOAJ, ERIC, Scopus, and Sinta (2015–2024). | 40 |
| Initial Screening | Screening based on title and abstract to assess relevance to PjBL and vocational education; duplicate and irrelevant studies removed. | 25 |
| Eligibility | Full-text review to ensure compliance with inclusion criteria (focus on PjBL, conceptual understanding, and/or critical thinking; empirical data present). | 12 |
| Final Inclusion | Articles meeting all criteria and possessing strong methodological quality included in the thematic synthesis. | 5 |

**Sumber:** Page, McKenzie, Bossuyt, and Boutron (2021)

The literature included in this study was deliberately limited to the sources presented in Table 1, taking into account the distinctive characteristics of vocational schools in Indonesia. These institutions operate under curricula, competency standards, and learning challenges that differ substantially from those of vocational education systems in other countries. Consequently, student characteristics and teacher readiness within the domestic vocational school context play a significant role in determining the successful implementation of Project-Based Learning (PjBL). Therefore, prioritizing literature grounded in the local context is considered more appropriate for providing an accurate and empirically relevant representation of the effectiveness of the PjBL model.

## Results and Discussion

The literature identification procedure followed the stages outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework. The initial search yielded 40 articles relevant to the research topic. Following a screening process based on titles and abstracts, 25 articles were considered suitable for further review. Subsequent full-text evaluation resulted in 12 articles meeting the predefined inclusion criteria: (a) empirical studies conducted within the context of Vocational High Schools (*Sekolah Menengah Kejuruan*/SMK) or equivalent vocational education institutions; (b) implementation of Project-Based Learning (PjBL); and (c) measurement of variables related to conceptual understanding and critical thinking skills. Based on the final synthesis, only five studies explicitly examined the relationship or the simultaneous effects of PjBL on both conceptual understanding and critical thinking skills. Overall, the

analysis revealed a consistent pattern supporting the effectiveness of PjBL in enhancing students' conceptual understanding and critical thinking abilities, although the majority of studies tended to investigate these two variables independently. A summary of the studies that met the final inclusion criteria is presented in Table 2.

**Tabel 2.** Summary of Studies Meeting the Final Inclusion Criteria

| No | Author(s) & Year | Research Focus | Method | Key Findings |
|---|---|---|---|---|
| 1 | Kamaruddin, Darmawati, Sudirman, and Handayani (2022) | Project Based Learning (Pjbl) with the Flipped Classroom Strategy on Students' Understanding and Critical Thinking | Quantitative (Descriptive statistics) | The use of the Project Based Learning (PjBL) learning model with a flipped classroom can have a positive impact on students' understanding and critical thinking. |
| 2 | Suci, Siburian, and Yelianti (2022) (DOAJ) | Implementation of the flipped classroom-based project-based learning model and its impact on critical thinking skills | Quasi-experiment with nonequivalent control group design. | Implementation of the Project-Based Learning Model Flipped Classroom-based learning has an impact on students' critical thinking skills. |
| 3 | Zhang, Guan, and Hu (2024) (Sprinklink) | Improving students' critical thinking (CT) skills through project-based learning (PBL) | Literature review with an independent study approach. | the prevailing contention within the domain of computational thinking education regarding the efficacy of project-based learning in nurturing computational thinking proficiencies. |
| 4 | Xie, Jantharajit, and Srikhao (2025) (ERIC) | Design of teaching objectives, integrating cooperative and project-based learning, the provisioning of learning resources and support, and the establishment of evaluation and feedback mechanisms | Methods Cooperative with Theory Study | To enhance PBCL, teachers should optimize project design and schools should allocate more resources. |
| 5 | Emily Williamson (2023) (Scopus Q1) | The study addressesa significant problem revealed by the National Assessment | The literature review outlines the | the positive impact of PBL on critical thinking, emphasizing its potential to enhance |

| | | | |
|---|---|---|---|
| | of Educational Progress, indicating a gap in critical thinking proficiency among high school students in the United States | theory of social constructivism, empirical findings | problem solving, analytical reasoning, and the application of knowledge in the real world. |

Of the five articles included in Table 2, one study, conducted by Emily Williamson (2023), is indexed in Scopus and published in a Q1-ranked journal. One article was sourced from the Directory of Open Access Journals (DOAJ), namely the study by Suci, Siburian, and Yelianti (2022), while another was retrieved from the ERIC database, specifically the study by Xie, Jantharajit, and Srikhao (2025). In addition, one article was accessed through SpringerLink, namely Zhang, Guan, and Hu (2024). Although it is listed as "Sprinklink" in the table, this designation refers to SpringerLink. The remaining article, conducted by Kamaruddin, Darmawati, Sudirman, and Handayani (2022), is not explicitly indexed in Scopus, DOAJ, ERIC, or SpringerLink and is therefore reasonably classified as having been sourced from Google Scholar. Based on the overall synthesis of the selected studies, it can be concluded that Project-Based Learning (PjBL) exerts a strong positive influence on students' critical thinking skills and conceptual understanding within vocational education contexts. Nevertheless, the findings also reveal that only a limited number of studies have simultaneously examined both constructs within a single research design, indicating a need for more integrative empirical investigations in future research.

**The Relationship between Conceptual Understanding and Critical Thinking Skills**

Project-Based Learning (PjBL) demonstrates a significant relationship with both conceptual understanding and critical thinking skills. By engaging students in authentic, real-world problem-solving activities, PjBL facilitates deeper conceptual comprehension as learners actively apply theoretical knowledge within meaningful contexts. This process supports the construction of mental models and enables students to establish connections between abstract concepts and practical applications, thereby strengthening their conceptual understanding (Hindun & Ramadhan, 2023).

In addition, PjBL fosters the development of critical thinking skills by requiring students to analyze information, evaluate alternative solutions, and reflect on their learning processes throughout the project cycle. The collaborative and inquiry-oriented nature of PjBL encourages learners to question assumptions, make informed decisions, and justify their reasoning, core components of critical thinking. By embedding these cognitive processes within project activities, PjBL creates a learning environment that is conducive to the development of higher-order thinking skills essential for success in the contemporary workforce (Mashudi, 2021).

However, a synthesis of the existing literature indicates that research in vocational education has predominantly examined conceptual understanding and critical thinking as separate outcomes when evaluating the effectiveness of Project-Based Learning. For example, Kamaruddin, Darmawati, Sudirman, and Handayani (2022) reported that PjBL

enhanced students' conceptual understanding through project activities that required the integration of theoretical knowledge and real-world practice. Similarly, Suci, Siburian, and Yelianti (2022) found that PjBL significantly improved vocational students' critical thinking skills, particularly in analytical and evaluative dimensions. Despite these positive findings, most studies have focused on only one of the two variables in isolation, resulting in a limited understanding of the causal and functional interrelationship between conceptual understanding and critical thinking within the PjBL framework.

Constructivist learning theory emphasizes that conceptual understanding serves as a foundational basis for the development of higher-order thinking skills. According to Az-Zahra, Rusdi, and Ristanto (2021), meaningful learning occurs when students actively construct conceptual representations through deep cognitive engagement. Such processes facilitate reflection, analysis, and evaluation, which constitute the core components of critical thinking. Consequently, when students develop strong conceptual understanding through relevant project-based learning experiences, they acquire a more robust cognitive framework that enables them to analyze problems systematically and make reasoned decisions.

Furthermore, findings from the synthesis indicate that variations in the implementation of Project-Based Learning (PjBL) across vocational education contexts significantly influence its effectiveness in enhancing both conceptual understanding and critical thinking skills. Sudarma and Nuryanto (2025) demonstrated that cross-disciplinary project-based learning substantially improved students' 4C skills, critical thinking, communication, collaboration, and creativity. Similarly, Rizani, Taufiqulloh, and Sudibyo (2022) reported that an IPAS-based PjBL module effectively enhanced critical thinking through structured inquiry-oriented activities. However, relatively few studies have systematically compared the effectiveness of different PjBL models, such as classroom-based, cross-disciplinary, and community-based projects, in simultaneously improving conceptual understanding and critical thinking skills.

Contextual factors also play a critical role in determining the effectiveness of PjBL within vocational school settings. Several studies (Andriyanto & Rahdiyanta, 2025; Hamidah, Sutrisno, & Nurbaiti, 2020) have confirmed that successful PjBL implementation is highly dependent on teachers' readiness to facilitate project-based instruction, the availability of adequate infrastructure, and effective project time management. Moreover, Hamidah, Rahmawati, and Syamsuddin (2020) found that PjBL significantly enhanced students' critical thinking, as evidenced by qualitative indicators of engagement and conceptual understanding. However, conceptual understanding was not explicitly measured as a quantitative variable in their study. This limitation highlights the need for research designs that simultaneously integrate both conceptual understanding and critical thinking, thereby providing more comprehensive empirical evidence not only of critical thinking outcomes but also of the role of conceptual understanding in supporting higher-order cognitive processes.

In summary, the effectiveness of Project-Based Learning (PjBL) in vocational education is determined not only by the quality of project design but also by the extent to

which the approach integrates students' conceptual understanding and metacognitive development. Consequently, future research should prioritize the development of PjBL frameworks that simultaneously assess conceptual understanding and critical thinking within a unified evaluative model. Such an approach is expected to yield a more comprehensive and nuanced understanding of PjBL's effectiveness in fostering 21st-century competencies among vocational students, while also offering meaningful theoretical and practical contributions to the advancement of vocational education curricula.

**Variations of Project-Based Learning Models and Implementation Contexts**

The literature analysis indicates that Project-Based Learning (PjBL) encompasses various implementation models that are adapted to learning contexts, student characteristics, and the availability of resources within vocational education settings. One increasingly prominent variation is blended Project-Based Learning (Zhang, Guan & Hu, 2024), which integrates face-to-face project activities with online learning components. This model enables students to engage in self-directed exploration through digital platforms while continuing to receive structured guidance and feedback from teachers during the project implementation process. Zhang, Guan, and Hu (2024) further argue that the design of PjBL must be carefully calibrated to align with students' developmental stages and contextual needs in order to fully realize its potential in fostering higher-order competencies, including computational and critical thinking skills.

Variations in PjBL design and implementation contexts have been shown to directly influence learning outcomes, particularly in the two key dimensions examined in this study: conceptual understanding and critical thinking skills. Williamson (2023) emphasized that although different PjBL models generally contribute to the development of higher-order thinking skills, their effectiveness is highly contingent upon several critical factors. These include (1) the context in which projects are implemented, (2) the nature and level of complexity of the assigned tasks, and (3) the readiness of both teachers and students to effectively manage and engage in project-based learning processes. Consequently, the alignment between project design, instructional context, and learner readiness is essential for maximizing the educational impact of PjBL in vocational education.

The literature analysis indicates that Project-Based Learning (PjBL) encompasses a range of implementation models that are adapted to specific learning contexts, student characteristics, and available resources within vocational education settings. One increasingly prominent variation is blended Project-Based Learning (Zhang, Guan, & Hu, 2024), which integrates face-to-face project activities with online learning components. This model enables students to engage in self-directed online exploration while continuing to receive direct instructional guidance from teachers during project execution. Zhang, Guan, and Hu (2024) further argue that the design of PjBL must be carefully calibrated to align with learners' developmental stages and age-specific characteristics in order to fully realize its potential for fostering higher-order and computational thinking skills.

Differences in project design and implementation contexts directly influence learning outcomes, particularly in relation to the two primary constructs examined in this study: conceptual understanding and critical thinking skills. Williamson (2023) emphasized that although various PjBL models generally contribute to the development of higher-order thinking skills, their effectiveness is largely contingent upon three key factors: (1) the context in which projects are implemented, (2) the type and level of complexity of the assigned tasks, and (3) the readiness of both teachers and students to manage project-based learning processes effectively.

In other words, the success of PjBL is not determined solely by the selected model, but also by how effectively it is adapted to real classroom conditions. For example, community-based PjBL implemented in tourism-related vocational schools has been shown to be effective in enhancing students' critical thinking skills through engagement in community-oriented projects, such as local tourism product development. This approach encourages learners to apply academic concepts to complex, real-world situations, thereby deepening conceptual understanding while simultaneously fostering analytical and reflective abilities. Conversely, in technical or automotive programs, laboratory-based PjBL tends to be more effective, as it provides hands-on opportunities for students to address technical problems directly. This finding aligns with Thomas (2020), who asserts that the effectiveness of PjBL is strongly influenced by the relevance of project tasks to students' fields of expertise and the extent to which projects require the simultaneous application of conceptual knowledge and critical thinking processes.

Despite these positive outcomes, the literature also reveals several persistent implementation challenges. First, many existing studies assess the success of PjBL primarily in terms of cognitive learning outcomes, while affective and metacognitive dimensions remain underexamined. Second, there is a notable lack of comparative research that directly evaluates the effectiveness of different PjBL models in simultaneously enhancing both conceptual understanding and critical thinking skills. Such comparative analyses are essential for understanding the interaction between project design, student characteristics, and targeted learning outcomes. Third, much of the existing PjBL research in SMK contexts focuses on specific vocational fields, such as automotive or electrical engineering, thereby limiting the generalizability of findings to other vocational disciplines.

Therefore, future research should adopt systematic and comparative approaches to evaluate the effectiveness of various PjBL models within vocational education. Mixed-methods research designs that integrate quantitative and qualitative data are particularly recommended. Such approaches would not only strengthen the empirical evidence base regarding the effectiveness of PjBL but also provide practical guidance for SMK teachers in selecting and adapting the most appropriate PjBL models to their specific classroom contexts. Ultimately, future studies are expected to address both theoretical and practical gaps concerning the relationship between PjBL model variations, implementation contexts, and their influence on the development of higher-order thinking skills among vocational students.

**External Factors Influencing the Effectiveness of PjBL**

The literature further indicates that the effectiveness of Project-Based Learning (PjBL) in Vocational High Schools (*Sekolah Menengah Kejuruan*/SMK) is influenced not only by instructional design and students' cognitive capacities but also by a range of external contextual factors. These factors include teacher readiness, infrastructure and resource availability, time allocation, student motivation, and school culture. Previous studies, such as those by Hamidah, Sutrisno, and Nurbaiti (2020), Williamson (2023), and Kamaruddin, Darmawati, Sudirman, and Handayani (2022), have consistently emphasized, either explicitly or implicitly, the critical role of contextual conditions in determining the successful implementation of PjBL.

Among these factors, teacher readiness emerges as the most influential determinant of PjBL effectiveness. In PjBL settings, teachers function not only as content deliverers but also as facilitators, project supervisors, and evaluators of both learning processes and outcomes. Hamidah, Rahmawati, and Syamsuddin (2020) reported that teachers' capacity to design contextually relevant projects and provide reflective guidance plays a pivotal role in fostering students' critical thinking skills. Teachers with a comprehensive understanding of PjBL principles are better positioned to align project activities with learning objectives that emphasize conceptual understanding and higher-order reasoning. This finding is supported by Prabawati and Suparman (2019), who investigated teachers' understanding of PjBL in public vocational schools in Yogyakarta. Their study revealed that although teachers generally possessed strong theoretical knowledge of PjBL, limited practical experience and insufficient professional training often constrained effective classroom implementation. In response to these challenges, teacher mentoring programs and professional learning communities have been shown to enhance educators' capacity to implement PjBL more effectively and sustainably (Hidayah, Puspa, & Apriyansa, 2021).

Second, the availability of facilities and learning resources significantly influences the effectiveness of Project-Based Learning (PjBL). Hamidah, Sutrisno, and Nurbaiti (2020) reported that limited laboratory facilities constrained the quantitative measurement of students' conceptual understanding, resulting in improvements being identified primarily through qualitative indicators of student responses. Similarly, Kamaruddin, Darmawati, Sudirman, and Handayani (2022) underscored the critical role of adequate infrastructure in the implementation of PjBL in chemistry instruction, particularly the availability of instructional materials and laboratory equipment. Ferwati, Junaidi, Napitupulu, and Hamid (2023) further reinforced this perspective by demonstrating that restricted access to technology and project-related resources constitutes a major challenge in implementing PjBL across various educational levels. In the context of vocational fashion design programs, Ayu and Suhartini (2021) found that the effectiveness of PjBL largely depends on the availability of appropriate practice spaces and relevant learning materials. Collectively, these findings indicate that the success of PjBL is determined not only by pedagogical design but also by the readiness and adequacy of the physical and material learning environment.

Third, project duration and curriculum load represent additional external factors affecting PjBL implementation. Project-Based Learning generally requires a longer instructional timeframe than conventional teaching methods due to its comprehensive stages, which include project planning, implementation, reflection, and evaluation. Emmily Williamson (2023) identified time constraints as a significant barrier for vocational teachers attempting to implement PjBL in a comprehensive manner, particularly within curricula that are densely packed and oriented toward competency-based assessment. Consistent with this finding, Liawati, Oktarina, and Rusdarti (2025) reported similar challenges in vocational accounting courses, where rigid scheduling often compelled teachers to abbreviate the exploration and reflection phases of project activities. As a result, learning outcomes related to critical thinking and conceptual understanding were less than optimal. Therefore, curriculum adjustments that provide greater flexibility in project timelines are essential to maximize the effectiveness of PjBL

Finally, student motivation and school culture play pivotal roles in determining the effectiveness of Project-Based Learning (PjBL). Emmily Williamson (2023) demonstrated that students' intrinsic motivation significantly influences project success, particularly in learning activities that require collaboration, creativity, and sustained engagement. Vocational schools that cultivate a culture of innovation, collaboration, and active learning tend to achieve more favorable outcomes than those that continue to adhere to traditional, teacher-centered instructional paradigms. Similarly, Liawati, Oktarina, and Rusdarti (2025) reported that student engagement increases substantially when project tasks are directly aligned with real-world industry needs and professional contexts. Moreover, a school culture that encourages experimentation, reflection, and the acceptance of failure as part of the learning process contributes meaningfully to the development of students' critical, reflective, and adaptive dispositions.

Taken together, motivational and cultural dimensions represent essential components that must be strengthened to maximize the educational impact of PjBL in vocational settings. In conclusion, the literature indicates that the effectiveness of PjBL in vocational education is shaped by a dynamic synergy between pedagogical design and external contextual factors. Teacher readiness and infrastructure availability function as foundational determinants of successful implementation, while student motivation and school culture facilitate the internalization of conceptual knowledge and the development of critical thinking skills. Accordingly, future research should systematically incorporate these external variables into empirical research designs in order to provide a more comprehensive and holistic understanding of PjBL effectiveness within vocational education contexts.

## Conclusion

This literature analysis confirms that Project-Based Learning (PjBL) consistently enhances vocational high school students' conceptual understanding and critical thinking skills. Nevertheless, a substantial research gap remains, as the majority of existing studies examine these two variables independently, resulting in an incomplete understanding of

their causal and functional interrelationships. Moreover, the effectiveness of PjBL is strongly influenced by external factors, including teacher preparedness, infrastructure availability, time allocation, and the presence of a collaborative school culture.

This study is limited by the relatively small number of publications that investigate the simultaneous effects of PjBL on conceptual understanding and critical thinking (only five articles), inconsistencies in measurement instruments, and the narrow focus on specific areas of vocational expertise, which constrains the generalizability of the findings. Accordingly, future research is recommended to employ mixed-methods designs to develop integrative assessment models that combine indicators of conceptual understanding and critical thinking within a unified evaluative framework. From a practical perspective, the successful implementation of PjBL in vocational high schools requires a transformation of teachers' roles toward facilitative and reflective instruction, supported by institutional policies that are responsive to the evolving demands of Industry 4.0.

## Ethical Statement

This study is a systematic literature analysis that synthesizes findings from previously published and publicly accessible scholarly articles. As such, it did not involve human participants, personal data collection, or experimental interventions. All sources included in the review were cited appropriately in accordance with academic integrity standards. The research was conducted in compliance with ethical guidelines for secondary research, ensuring transparency, accuracy, and respect for the intellectual property of original authors.

## CRediT Authorship Contribution Statement

- **Author 1**: Conceptualization; Methodology; Investigation; Writing – Original Draft.
- **Author 2**: Conceptualization; Review & Editing; Formal Analysis.
- **Author 3**: Collecting data; Review & Editing; Formal Analysis.

## Conflict of Interest

The authors declare that there are no competing financial interests or personal relationships that could have influenced the work reported in this article.

## Data Availability

The datasets generated and analyzed during the current study are available upon reasonable request

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