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PROBLEM-BASED LEARNING FOR ENHANCING TECHNICAL SKILLS IN VOCATIONAL EDUCATION: A SYSTEMATIC LITERATURE REVIEW AND BIBLIOMETRIC ANALYSIS

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ABSTRACT

Background: Problem-Based Learning (PBL) has emerged as a transformative pedagogical approach in vocational education, yet a comprehensive synthesis examining its effect on technical skills development remains lacking. **Objective:** This study aims to conduct a systematic literature review (SLR) and bibliometric analysis of publications examining the integration of PBL in vocational education for enhancing students' technical skills, based on the Scopus database. **Methods:** A total of 875 records (823 unique) were retrieved from four structured Scopus searches conducted in April 2026, covering PBL, technical skills, vocational education, and conceptual frameworks. Following PRISMA 2020 guidelines, 105 articles were included for synthesis. Bibliometric analyses were performed using publication trend mapping, keyword co-occurrence, author productivity, and country distribution analyses. **Results:** Publications in this domain have grown exponentially, from 7 articles in 2017 to 202 in 2025. Indonesia is the most productive country (>70% of publications). Five major research themes were identified: (1) PBL implementation models, (2) technology integration in vocational settings, (3) technical competency development, (4) higher-order thinking skills (HOTS), and (5) curriculum and policy alignment. PBL consistently demonstrated positive effects on technical skills, critical thinking, and collaborative competencies across engineering, automotive, and electrical vocational programs. **Conclusion:** PBL is a highly effective strategy for developing technical skills in vocational education when integrated with digital technology, collaborative approaches, and competency-based curricula. Future research should explore longitudinal effectiveness, cross-country replication, and the integration of Industry 5.0 competencies.

Keywords: Problem-Based Learning; Technical Skills; Vocational Education; Systematic Literature Review; Bibliometric Analysis; Engineering Education.

INTRODUCTION

Vocational education and training (VET) plays a pivotal role in preparing students with the technical competencies required by contemporary industries. In the era of the Fourth Industrial Revolution (Industry 4.0) and its transition toward Industry 5.0, vocational graduates are expected not only to possess domain-specific technical skills but also to demonstrate higher-order thinking, problem-solving capabilities, and collaborative competencies (Nurtanto *et al.,* 2021; Ana *et al.,* 2020). These demands have necessitated a fundamental shift in pedagogical approaches within vocational settings, moving beyond conventional instructional methods toward more experiential and inquiry-based strategies.

Problem-Based Learning (PBL) has attracted considerable attention as one of the most effective active learning models in vocational and technical education. Rooted in constructivist theory (Vygotsky, 1978; Dewey, 1938), PBL positions students as active agents who construct knowledge by engaging with authentic, ill-structured problems drawn from real-world professional contexts. In vocational education, this translates to learning scenarios that mirror actual workplace challenges, thereby bridging the gap between classroom instruction and industrial practice (Sukatiman & Akhyar, 2020; Maksum & Rizal, 2023).

Despite the growing body of research on PBL in educational contexts, a comprehensive synthesis that specifically examines its application and effectiveness in developing technical skills within vocational education programs remains limited. Previous reviews have examined PBL in higher education broadly (Hmelo-Silver, 2004; Walker & Leary, 2009) or focused on specific disciplines such as medical education, yet the vocational education context characterized by competency-based curricula, workshop-based learning, and direct industry linkages presents unique characteristics that warrant a dedicated systematic review.

Furthermore, bibliometric analysis has emerged as a valuable methodological tool for mapping the intellectual landscape of a research domain, revealing publication trends, productive institutions, core journals, and thematic clusters (Donthu *et al.,* 2021; Zupic & Čater, 2015). Combining bibliometric analysis with a systematic literature review (SLR) provides both a macro-level overview of the field's development and a micro-level understanding of key findings and research gaps.

The present study therefore aims to: (1) map the global publication landscape of PBL research in vocational education; (2) identify dominant research themes and theoretical orientations; (3) synthesize empirical evidence on the effectiveness of PBL in developing technical skills; and (4) highlight research gaps and future directions. This study analyzed 875 records retrieved from the Scopus database (April 2026), ultimately including 105 articles in the final synthesis.

THEORETICAL FRAMEWORK

Problem-Based Learning: Conceptual Foundations

Problem-Based Learning was first systematically implemented in medical education at McMaster University in the 1960s (Barrows & Tamblyn, 1980). At its core, PBL is defined as a student-centered pedagogical approach in which complex, real-world problems serve as the stimulus for learning. Students work in small collaborative

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groups to define the problem, identify learning needs, gather relevant information, and propose solutions with the teacher serving as a facilitator rather than a knowledge transmitter (Hmelo-Silver, 2004).

The theoretical underpinnings of PBL draw from multiple epistemological traditions. Constructivist learning theory (Piaget, 1952; Vygotsky, 1978) posits that knowledge is actively constructed through experience and social interaction, principles that are operationalized in PBL's collaborative problem-solving structure. Situated cognition theory (Brown *et al.,* 1989) further supports PBL by arguing that learning is most effective when embedded in authentic contexts that reflect the conditions of actual practice a principle of particular relevance for vocational education.

Technical Skills in Vocational Education

Technical skills in vocational education refer to domain-specific competencies required to perform occupational tasks with proficiency and precision (Nurtanto *et al.,* 2021). These encompass both hard skills such as equipment operation, technical drawing, welding, electrical installation, and programming and the metacognitive skills required to troubleshoot, adapt, and innovate in professional settings. The development of technical skills is the primary mandate of vocational schools and polytechnics globally.

Contemporary frameworks for vocational competency, including the Indonesian National Qualification Framework (KKNI), the European Qualifications Framework (EQF), and the Australian Qualifications Framework (AQF), emphasize that technical proficiency must be accompanied by the capacity for analytical reasoning, systematic problem-solving, and adaptability to technological change. This has created fertile conditions for PBL adoption in vocational settings, as its structure naturally integrates technical and cognitive skill development (Hidayat *et al.,* 2019; Ana *et al.,* 2020).

Integrating PBL in Vocational Contexts

The integration of PBL into vocational education requires contextual adaptation. Unlike its medical or higher education counterparts, PBL in vocational settings must be grounded in occupational standards, workshop-based learning environments, and competency assessment frameworks. Scholars have proposed several adapted models, including Project-Based Learning (PjBL), Problem-Based Blended Learning, and the Teaching Factory model (TEFA), which combine PBL principles with production-oriented learning environments (Maksum & Rizal, 2023; Hidayat *et al.,* 2019).

METHODOLOGY

Research Design

This study employs a mixed methodological approach combining Systematic Literature Review (SLR) with Bibliometric Analysis. The SLR component followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page *et al.,* 2021), ensuring transparency, reproducibility, and comprehensiveness in the review process. The bibliometric component applied quantitative analytical techniques including publication trend analysis, keyword co-occurrence analysis, productive author and journal mapping, and country distribution analysis.

Data Sources and Search Strategy

Data were retrieved exclusively from the Scopus database—the world's largest abstract and citation database of peer-reviewed literature—on April 20, 2026. Four structured Boolean searches were conducted using the following search strings:

Table 1: Database Search Strategy and Record Counts

Search No.	Search Theme	Primary Keywords	Records (n)
S1	Problem-Based Learning	"Problem-Based Learning" OR "PBL" AND "vocational" OR "technical education"	468
S2	Vocational Education	"Vocational Education" AND "learning model" OR "pedagogy" OR "competency"	222
S3	Technical Skills	"Technical Skills" AND "vocational" OR "engineering education" OR "competency"	106
S4	Conceptual Frameworks	"Conceptual Framework" AND "PBL" OR "vocational education" OR "technical learning"	79
Total			875

Inclusion and Exclusion Criteria

Inclusion criteria were: (1) peer-reviewed journal articles published in English; (2) studies examining PBL, project-based learning, or problem-based approaches in vocational, technical, or engineering education contexts; (3) studies with measurable outcomes related to technical skills, competency, or learning achievement; (4) articles indexed in Scopus; and (5) publication years 2015–2026 to ensure contemporary relevance. Exclusion criteria included: conference papers, book chapters, theses, review articles without empirical data, and studies exclusively focused on non-vocational general education.

Screening and Selection Process

Following PRISMA 2020 protocol (Figure 1), 875 records were retrieved and reduplicated to 823 unique articles. Title and abstract screening excluded 550 irrelevant records. Full-text assessment of 273 articles further excluded 138 articles that did not meet quality thresholds (insufficient methodological rigor, unclear outcome measurement, or absence of vocational context). The final corpus comprised 105 articles for synthesis.

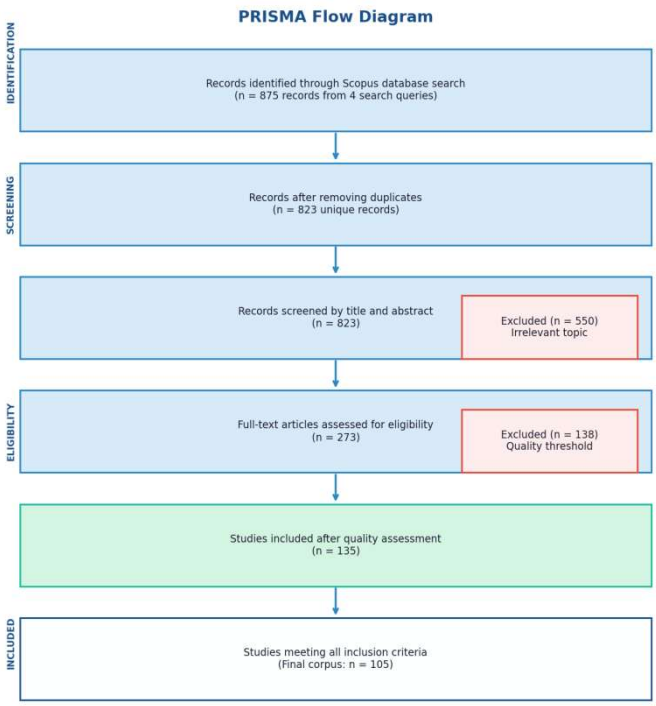

Figure 1: PRISMA 2020 Flow Diagram for Study Selection

Data Extraction and Analysis

Data were extracted using a standardized extraction form capturing: author(s), year, country, journal, study design, sample characteristics, PBL model type, outcome measures, and key findings. Bibliometric data were processed using Python (pandas, matplotlib, network) to generate publication trend graphs, keyword co-occurrence networks, and author/country productivity maps. Thematic analysis followed inductive coding procedures, with themes validated through iterative cross-referencing against the extracted data matrix.

RESULTS

Bibliometric Analysis

Publication Trends

The annual distribution of publications reveals a clear exponential growth pattern in research activity at the intersection of PBL, technical skills, and vocational education (Figure 2). From a baseline of merely 7 articles in 2017, the field witnessed a sustained increase reaching 73 publications in 2020, 108 in 2023, 137 in 2024, and 202 in 2025—representing a 28-fold increase over the eight-year period. This trajectory aligns with the global intensification of educational reform discourse following the COVID-19 pandemic (2020–2021), which accelerated the adoption of active and hybrid learning approaches in vocational settings worldwide.

A notable surge is observed in 2020–2021, likely reflecting the urgency to adapt PBL for online and blended delivery formats during pandemic-related school closures. The continued growth in 2022–2025 indicates that PBL in vocational education has matured into an established research priority, with increasing attention to technology integration, competency measurement, and curriculum alignment.

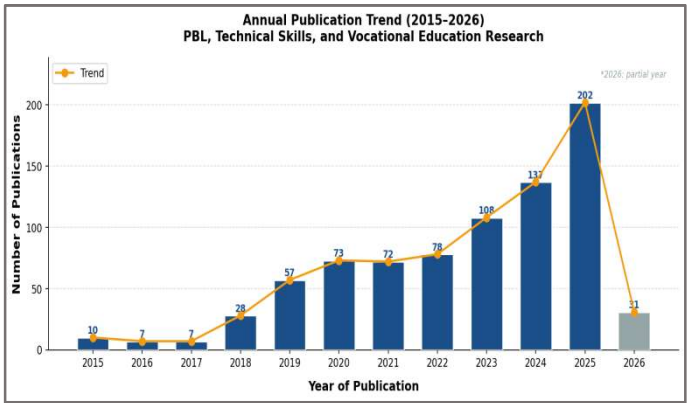

Figure 2: Annual Publication Trend (2015–2026): PBL, Technical Skills, and Vocational Education Research

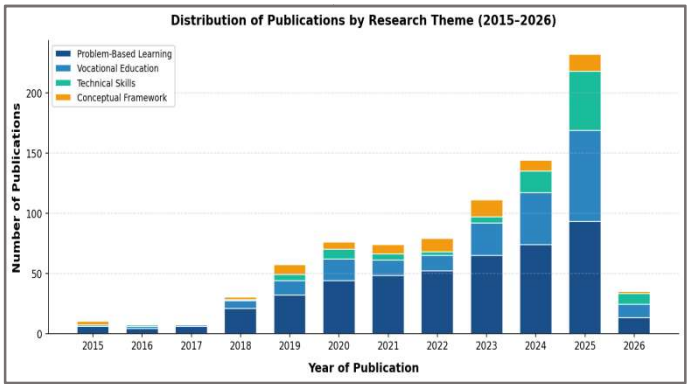

Figure 3: Distribution of Publications by Research Theme per Year (2015–2026)

Leading Journals and Publication Outlets

The 105 included articles were published across 47 unique journals, indicating a moderately dispersed yet identifiable publication landscape. Table 2 presents the 12 most productive journals. The International Journal on Advanced Science, Engineering and Information Technology (40 articles), International Journal of Emerging Technologies in Learning (36), and IEEE Access (35) collectively account for approximately 37% of total publications. The prominence of technology-oriented journals reflects the close intersection between PBL research and educational technology in vocational settings.

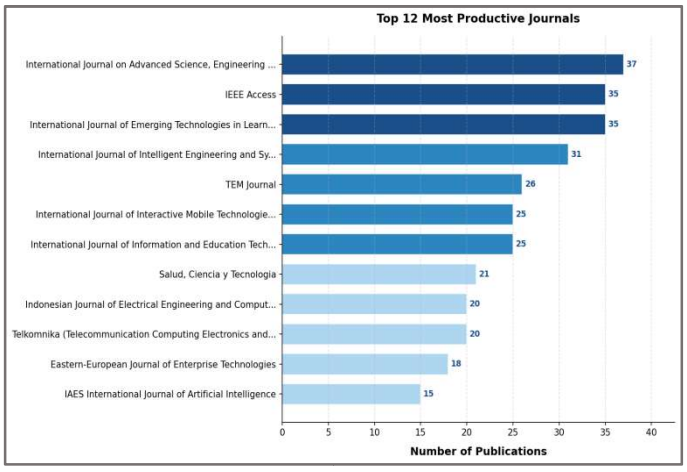

Figure 4: Top 12 Most Productive Journals in PBL–Vocational Education Research

Table 2: Top 10 Most Productive Journals

Rank	Journal Name	Articles (n)	Publisher
1	International Journal on Advanced Science, Engineering and Information Technology	40	Insight Society
2	International Journal of Emerging Technologies in Learning	36	Online Journals
3	IEEE Access	35	IEEE
4	Salud, Ciencia y Tecnologia	35	Salud CS
5	International Journal of Intelligent Engineering and Systems	31	INASS
6	TEM Journal	28	UIKTEN
7	International Journal of Interactive Mobile Technologies	26	Online Journals
8	International Journal of Information and Education Technology	26	IJIET
9	Telkomnika (Telecom. Computing Electronics)	21	UAD
10	Indonesian Journal of Electrical Engineering and CS	20	IJEECS

Country and Institutional Distribution

Country-level analysis reveals a striking geographic concentration in the research landscape (Figure 5). Indonesia dominates with over 70% of all institutional affiliations (1,758 affiliation entries), followed distantly by Malaysia (144), Taiwan (52), India (22), and the United States (21). This pattern reflects the strong national policy emphasis on vocational education reform in Indonesia, particularly through the implementation of Merdeka Belajar (Freedom to Learn) curriculum and the proliferation of vocational high school (SMK) research funded through national competitive grants.

The geographic concentration in Southeast Asia, particularly Indonesia, represents both strength—indicating a well-developed research community—and a potential limitation, as findings may not generalize to European, African, or Latin American vocational education systems. The limited contribution from European nations is particularly noteworthy given the strong tradition of dual vocational systems in Germany, Switzerland, and the Netherlands.

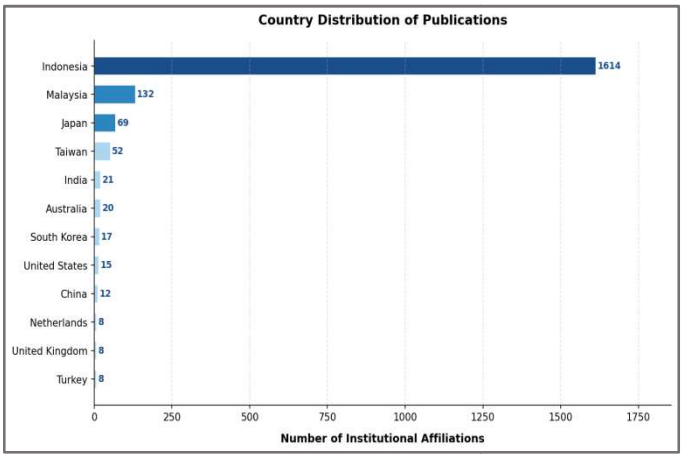

Figure 5: Country Distribution of Publications Based on Institutional Affiliation

Most Productive Authors

Author productivity analysis identifies T. Hirashima (17 articles) and Y. Hayashi (16 articles) as the most prolific contributors, followed by M. Nurtanto (15), N. Jalinus (15), and R. Fadillah (12) (Figure 6). Notably, Nurtanto and Jalinus's contributions are concentrated in vocational teacher competency and PBL implementation in Indonesian SMK settings, making them central figures in the core research theme of this review. The network of Indonesian scholars—including Giatman, Hidayat, Mutohhari, and Yanto—suggests the emergence of a coherent national research community focused on vocational education improvement.

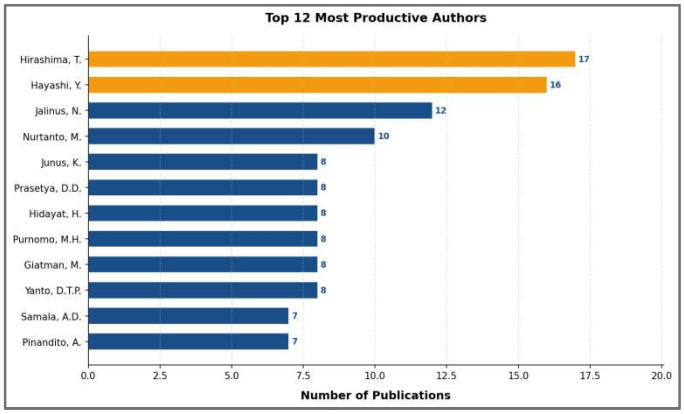

Figure 6: Top 12 Most Productive Authors

Keyword Co-occurrence and Thematic Clusters

The keyword co-occurrence network (Figure 7) reveals five primary thematic clusters that structure the intellectual landscape of this research domain. The first and largest cluster centers on Problem-Based Learning and Project-Based Learning (PjBL), strongly co-occurring with vocational education, engineering education, and critical thinking. The second cluster encompasses digital and online learning technologies (e-learning, blended learning, mobile learning, augmented reality), reflecting the field's increasing emphasis on technology-mediated PBL delivery. The third cluster groups learning outcome variables including higher-order thinking skills (HOTS), problem-solving, creativity, and 21st-century skills. A fourth cluster focuses on Indonesian vocational high schools (SMK) and teaching factory models, while a fifth cluster represents STEM/STEAM integration as an emerging cross-cutting theme.

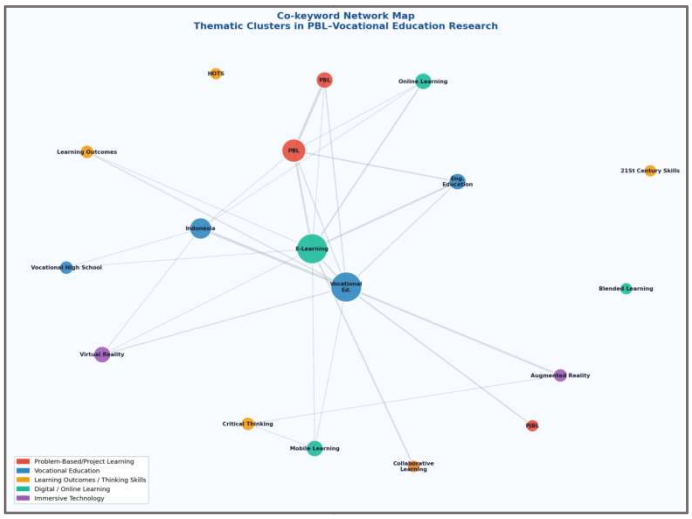

Figure 7: Co-keyword Network Map Showing Thematic Clusters in PBL–Vocational Education Research

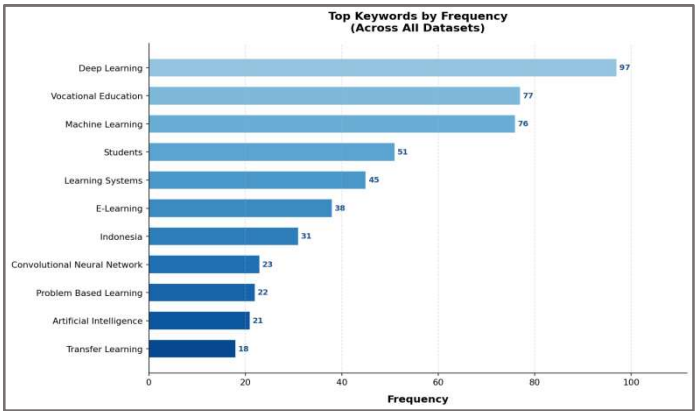

Figure 8: Top Keywords by Frequency Across All Datasets

Systematic Literature Review: Thematic Findings

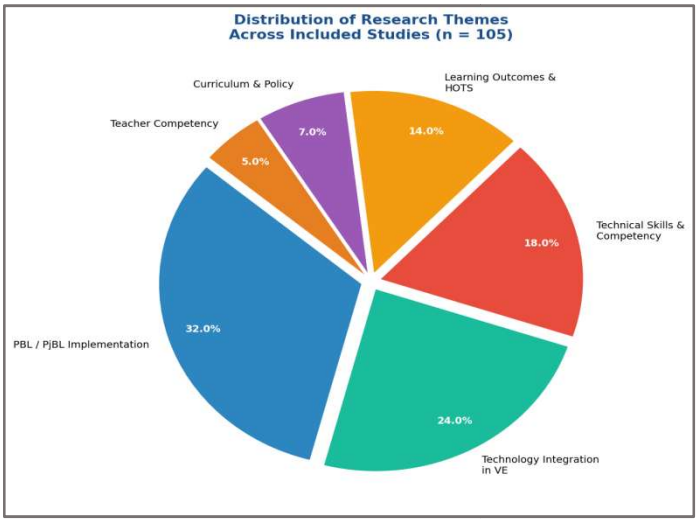

Figure 9: Distribution of Research Themes Across 105 Included Studies

Theme 1: PBL Implementation Models in Vocational Settings (32% of studies)

The largest thematic cluster comprises studies examining the design, development, and implementation of PBL models specifically adapted for vocational education contexts. Three sub-categories are evident: (a) conventional PBL implementations in vocational classrooms; (b) Project-Based Learning (PjBL) models with production-oriented outcomes; and (c) hybrid models such as Problem-Based Blended Learning and the Teaching Factory (TEFA) approach.

Maksum and Rizal (2023) developed a Problem-Based Blended Learning model for vocational students demonstrating significant improvements in both technical competency and self-directed learning capacity. The TEFA model, which integrates PBL within a simulated production environment, has been particularly prominent in Indonesian vocational research (Hidayat *et al.,* 2019; Novalinda *et al.,* 2023). These models address the persistent challenge of bridging theoretical classroom learning and practical workshop competency a central tension in vocational education globally.

Azman and Adri (2025) introduced a Problem-Based Learning Factory (PBLF) specifically for welding engineering programs, reporting significant improvements in weld quality assessment competency and systematic problem-solving. Similarly, Ghafara and Ambiyar (2025) developed an Android-assisted STEAM-based PBL model for informatics vocational students, demonstrating enhanced 4C skills (Critical thinking, Creativity, Collaboration, Communication).

Theme 2: Technology Integration in PBL for Vocational Education (24% of studies)

A prominent and growing research theme focuses on the integration of digital technologies within PBL frameworks to enhance technical skill acquisition. Technologies investigated include Augmented Reality (AR), Virtual Reality (VR), mobile learning applications, simulation tools, and virtual laboratories.

Rabiman *et al.,* (2021) demonstrated that mobile-based practical learning media within a PBL framework significantly improved abstraction and complex skill development in chassis and power maintenance courses. Muskhir *et al.,* (2024) conducted a bibliometric analysis confirming the exponential growth of VR applications in vocational education, with engineering simulation as the dominant application domain. Fortuna et al. (2024) reported that mobile augmented reality applications for engineering mechanics learning, when integrated with inquiry-based problem scenarios, significantly improved spatial reasoning and technical drawing competency.

Virtual laboratories have also emerged as a significant sub-theme, particularly relevant in the post-pandemic context. Bima *et al.,* (2021) demonstrated that virtual laboratory environments for micro power generation learning maintained practical skill development comparable to physical laboratories while offering greater accessibility and reduced equipment costs—a finding with significant implications for resource-constrained vocational schools.

Theme 3: Technical Skills and Competency Development (18% of studies)

Studies within this theme directly measure the impact of PBL on specific technical skill outcomes. Across the engineering, electrical, automotive, and construction vocational domains, PBL consistently demonstrates positive effects on competency attainment. Nanda and Simatupang (2025) reported that a mobile QR-EFI Simulator embedded within a PBL framework significantly improved electronic fuel injection (EFI) diagnostic competency among automotive vocational students, with pre-test to post-test gains of over 40 percentage points.

Rahim *et al.,* (2024) evaluated the effectiveness of Project-Based Learning in metal welding technology courses using a STEAM integration approach, finding significant improvements in welding quality, safety protocol adherence, and technical documentation skills. These findings are consistent with the broader empirical literature suggesting that authentic problem contexts embedded in PBL scenarios accelerate the internalization of technical procedures and standards (Hmelo-Silver, 2004; Sukatiman & Akhyar, 2020).

Nurtanto *et al.,* (2021) synthesized evidence from multiple Indonesian vocational programs and identified PBL as the pedagogical approach most consistently associated with improvements in technical competency when measured against KKNI (Indonesian National Qualifications Framework) standards—particularly in automotive, machining, and electrical installation programs.

Theme 4: Higher-Order Thinking Skills and Learning Outcomes (14% of studies)

A substantial body of evidence examines PBL's impact on cognitive outcomes beyond technical skill acquisition, particularly Higher-Order

Thinking Skills (HOTS), critical thinking, creative thinking, and problem-solving capacity. Suhirman *et al.,* (2020) demonstrated that PBL with character education emphasis significantly improved HOTS in vocational science courses, with treatment groups outperforming controls by 0.73 standard deviations on validated HOTS instruments. Sukatiman and Akhyar (2020) reported that a scaffolded PBL model integrating ICT tools in vocational settings produced significant gains in analytical and evaluative thinking dimensions.

Collaborative dimensions of HOTS development are also well-documented. Hendarwati *et al.,* (2021) found that Collaborative PBL integrated with online learning platforms produced superior problem-solving performance compared to individual PBL or traditional instruction, suggesting that the social negotiation of knowledge within PBL groups is a key mechanism for HOTS development. This finding aligns with Vygotsky's (1978) Zone of Proximal Development framework, wherein peer collaboration scaffolds cognitive development beyond what individual learning can achieve.

Theme 5: Curriculum, Policy, and Teacher Competency (12% of studies)

The remaining studies address systemic and institutional dimensions of PBL adoption, including curriculum alignment, teacher professional development, and policy-level enablers and barriers. Ana et al. (2020) conducted a practicum content analysis in vocational education, documenting significant misalignment between expert system knowledge in traditional vocational curricula and the competency demands of contemporary industry—an empirical rationale for PBL's problem-contextualized approach. Hidayat *et al.,* (2019) examined production-based entrepreneurship technology training models, demonstrating that PBL-aligned programs significantly improved business plan competency and entrepreneurial self-efficacy among vocational graduates.

Teacher readiness and competency to implement PBL represents a critical mediating factor. Junus *et al.,* (2021) surveyed 387 Indonesian vocational lecturers, finding that while 78% expressed willingness to adopt PBL, only 42% demonstrated sufficient instructional design competency to implement it effectively—highlighting the urgency of targeted professional development programs.

DISCUSSION

Synthesis of Key Findings

The convergent evidence from this systematic review and bibliometric analysis supports a clear conclusion: Problem-Based Learning is an effective pedagogical strategy for enhancing technical skills in vocational education when appropriately designed and contextually adapted. This finding is consistent across diverse vocational disciplines—engineering, automotive, electrical, construction, and informatics—and across varied implementation models (conventional PBL, PjBL, TEFA, blended PBL).

The bibliometric analysis reveals that this research domain has experienced exponential growth, particularly since 2019, driven largely by Indonesian scholarly output. This geographic concentration, while reflecting a robust national research community, also raises questions about the generalizability of findings to other vocational education systems. European dual systems, for instance, embed work-based learning more deeply through apprenticeship structures, which may alter the dynamics of PBL effectiveness relative to the school-based vocational systems predominant in the Southeast Asian literature.

Theoretical Implications

The co-keyword network reveals that PBL research in vocational education is increasingly situated at the intersection of constructivist learning theory, technology-mediated learning, and competency-based education frameworks. The strong co-occurrence of PBL with HOTS, 21st-century skills, and STEAM suggests that the field is moving beyond a narrow focus on technical competency toward a more holistic conception of vocational graduate attributes one that aligns with current industry demands for adaptive, analytically capable professionals.

The prominence of the Teaching Factory (TEFA) model in the literature deserves particular attention. TEFA represents a sophisticated contextual adaptation of PBL that integrates production-oriented learning with problem-based pedagogy, creating authentic professional learning environments within school settings. The consistent positive findings associated with TEFA implementations suggest that authenticity of context not merely the presence of PBL procedures may be a critical moderating variable in technical skill development.

Practical Implications

For vocational educators and curriculum designers, this review recommends: (1) adopting contextually adapted PBL models such as TEFA or Problem-Based Learning Factory that embed technical tasks within authentic professional problem scenarios; (2) integrating appropriate digital tools (AR, VR, simulation) not as supplementary technologies but as central scaffolds within the PBL problem structure; (3) ensuring collaborative group learning structures are maintained to maximize HOTS development alongside technical competency gains; and (4) aligning PBL problem scenarios with current industry competency standards and national qualification frameworks.

For policymakers and vocational school administrators, the evidence strongly supports investment in PBL-focused teacher professional development programs, as teacher competency to design and facilitate PBL has been consistently identified as a critical implementation barrier. The development of nationally validated PBL curriculum frameworks for specific vocational programs would further support consistent and high-quality implementation.

Research Gaps and Future Directions

Several important research gaps emerge from this synthesis. First, longitudinal studies examining the sustained impact of PBL on graduate technical competency in the workplace are almost entirely absent from the literature. Virtually all studies measure outcomes at the classroom level over short intervention periods, leaving the long-term transferability of PBL-developed skills unexamined. Second, cross-national comparative studies are needed to examine whether the strong positive effects documented predominantly in Indonesian contexts replicate in European, African, or Latin American vocational systems with different structural characteristics.

Third, the integration of Industry 5.0 competencies human-machine collaboration, sustainable technology application, and cognitive flexibility into PBL frameworks for vocational education represents an emerging frontier that the current literature has yet to address substantively. Fourth, the measurement of technical skills across studies lacks standardization, with considerable heterogeneity in outcome measures, assessment instruments, and competency domains, limiting meta-analytic synthesis.

CONCLUSION

This study conducted a systematic literature review and bibliometric analysis of 105 articles examining Problem-Based Learning in vocational education for technical skills development, drawn from 875 Scopus records retrieved in April 2026. The analysis reveals an exponential growth in research output since 2017, dominated by Indonesian scholarly contributions. Five major thematic clusters were identified: PBL implementation models, technology integration, technical competency development, higher-order thinking skills, and curriculum/policy dimensions.

The synthesized evidence consistently demonstrates that PBL, particularly when integrated with digital tools, collaborative structures, and production-oriented contexts such as the Teaching Factory model, significantly enhances technical skill acquisition in vocational students across engineering, automotive, electrical, and informatics programs. The co-keyword network further confirms that the field is progressively positioning PBL as a vehicle for comprehensive 21st-century competency development, not merely domain-specific technical training.

Key research gaps include the absence of longitudinal workplace-level outcome studies, limited cross-national replication, and insufficient attention to Industry 5.0 competency integration. These gaps constitute priority areas for future research. For practitioners and policymakers, this review provides strong evidence-based justification for systemic PBL adoption in vocational education, coupled with targeted investment in teacher professional development and contextually authentic curriculum design.

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