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Transforming Teachers Through Project-Based Learning: A Systematic Literature and Network Analysis

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Abstract

Following PRISMA 2020 guidelines, this systematic literature and network analysis examined 18 empirical studies (2020-2024) from Scopus database investigating project-based learning (PBL) teacher training models. VOSviewer bibliometric analysis of 330 keyword co-occurrence networks complemented the systematic review. Results identified five essential training components: theoretical understanding, hands-on practice, structured reflection, collaborative learning, and sustained mentoring. Teacher transformation progressed across three dimensions—pedagogical competence, teaching self-efficacy, and classroom implementation skills—with persistent challenges in classroom management, time allocation, and curriculum alignment. Bibliometric analysis positioned research at the convergence of pedagogical innovation, professional development theory, and technological integration, with COVID-19 as a catalytic network node and artificial intelligence representing the most recent frontier. Practical implications: Effective PBL teacher training requires phase-based, scaffolded programs (6-12 months) embedding authentic practice within collaborative professional learning communities and sustained institutional support including dedicated planning time and resource allocation.

Keywords: *project-based learning, teacher training, professional development, systematic review, teacher transformation*

Introduction

Project-based learning (PBL) has emerged as a critical pedagogical approach globally for cultivating essential 21st-century competencies such as critical thinking, collaboration, and creativity (Kokotsaki et al., 2016; Krajcik & Shin, 2014). Its successful implementation hinges on a fundamental transformation of teachers' roles from transmitters of knowledge to facilitators of student-centered learning (Condliffe et al., 2017). This profound shift necessitates significant pedagogical changes, the acquisition of new competencies, and sustained support structures for educators. Without this role transformation, the potential of PBL to foster deep, authentic learning remains unrealized. Consequently, specialized teacher training is paramount for the effective adoption and integration of PBL across diverse educational settings.

Recent research has documented several essential components of effective PBL teacher training. These components include experiential learning cycles, explicit instruction on facilitation techniques, and opportunities for supported practice (Thomas, 2000). Other studies have examined teachers' beliefs and attitudes as critical determinants of their readiness and implementation success (Ariyani et al., 2024; Cai et al., 2023). Further investigations have focused on persistent implementation challenges in classroom settings, such as managing project complexity and time constraints (Clark & Shin, 2024; Fang et al., 2023). Broader research on professional development has identified key characteristics of effective programs, emphasizing content focus, active learning, and sufficient duration (Darling-Hammond et al.,

2017). Despite these advancements, a consolidated synthesis of evidence regarding specific training models designed to *facilitate* this transformation is still needed.

Three critical gaps persist in the current body of literature on PBL teacher preparation. First, existing systematic reviews often prioritize implementation outcomes in students over the analysis of training models that develop teacher capacity (Guo et al., 2020). Second, while syntheses on generic professional development exist (Desimone & Garet, 2015), they frequently overlook the transformation-specific demands of the instructor-to-facilitator shift, which requires role reconceptualization beyond mere skill acquisition (Larmer et al., 2015). Third, conventional systematic reviews tend to present findings in isolation from the broader intellectual and temporal context. This approach misses crucial insights into how research themes evolve in response to societal disruptions and technological innovations (Borrego et al., 2014). Addressing this last gap is particularly urgent given the transformative period of 2020-2024.

The chosen timeframe (2020-2024) represents a period of significant catalytic events reshaping teacher professional development. The COVID-19 pandemic forcibly accelerated the shift to online and hybrid training modalities, acting as a major disruptor and innovation driver (Trust & Whalen, 2020). Simultaneously, advancements in artificial intelligence began promising new frontiers for personalized and scalable teacher preparation support (Holmes et al., 2019). These concurrent developments create a unique context for examining contemporary PBL training models. Therefore, a focused analysis of recent empirical evidence is necessary to understand how training designs have adapted. This study is positioned to capture these evolving dynamics and their implications for teacher transformation.

This study addresses the identified gaps by pursuing four primary research questions concerning the essential components of PBL training, the dimensions of teacher development, persistent barriers, and the scholarly positioning of this research domain. It introduces novelty through a threefold contribution: methodological, topical, and temporal. Methodologically, it employs an integrated Systematic Literature and Network Analysis (SLNA), combining a PRISMA-guided review with bibliometric mapping using VOSviewer (van Eck & Waltman, 2010; Page et al., 2021). Topically, it focuses explicitly on mechanisms for instructor-to-facilitator transformation rather than generic development outcomes. Temporally, it analyzes evidence from 2020-2024 to capture the catalytic effects of recent global and technological shifts on teacher professional development paradigms.

Method

This integrated systematic literature and network analysis followed PRISMA 2020 guidelines (Page et al., 2021) for the systematic review component while employing VOSviewer software (van Eck & Waltman, 2010) for bibliometric keyword network analysis.

Study Design

This study employed a convergent mixed-methods systematic literature and network analysis (SLNA) design integrating two complementary approaches. The systematic review component synthesized empirical evidence from primary studies examining PBL teacher training interventions, focusing on program components, transformation outcomes, and implementation challenges. The bibliometric network analysis component examined keyword co-occurrence patterns across a broader corpus to position systematic findings within evolving research landscapes.

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Search Strategy and Data Sources

A comprehensive literature search was conducted in Scopus database covering publications from January 2020 to December 2024. Scopus was selected for three reasons: (1) comprehensive coverage of education research journals with superior indexing of recent publications compared to alternative databases, (2) standardized metadata facilitating bibliometric analysis, and (3) inclusion of both high-impact and emerging journals ensuring representation of diverse educational contexts.

The search strategy combined keywords using Boolean operators:

Search string: (("project-based learning" OR "project based learning" OR "PBL") AND ("teacher training" OR "teacher education" OR "professional development" OR "teacher preparation" OR "preservice teacher" OR "in-service teacher") AND ("transformation" OR "facilitation" OR "role change" OR "pedagogical shift" OR "implementation" OR "training program"))

Filters applied: Article type (peer-reviewed journal articles), Language (English), Publication date (2020-2024). The five-year timeframe captured contemporary training models shaped by COVID-19 pandemic effects and emerging technological innovations while ensuring manageable scope and currency of findings. The initial search yielded 330 records, which underwent systematic screening following PRISMA guidelines.

Eligibility Criteria and Study Selection

Studies were included if they were empirical research employing quantitative, qualitative, or mixed methods designs; focused on K-12 or higher education teacher training programs; explicitly examined PBL-specific professional development interventions; and measured teacher-level outcomes. Table 1 presents the complete inclusion and exclusion criteria used for study selection.

Table 1. Inclusion and Exclusion Criteria

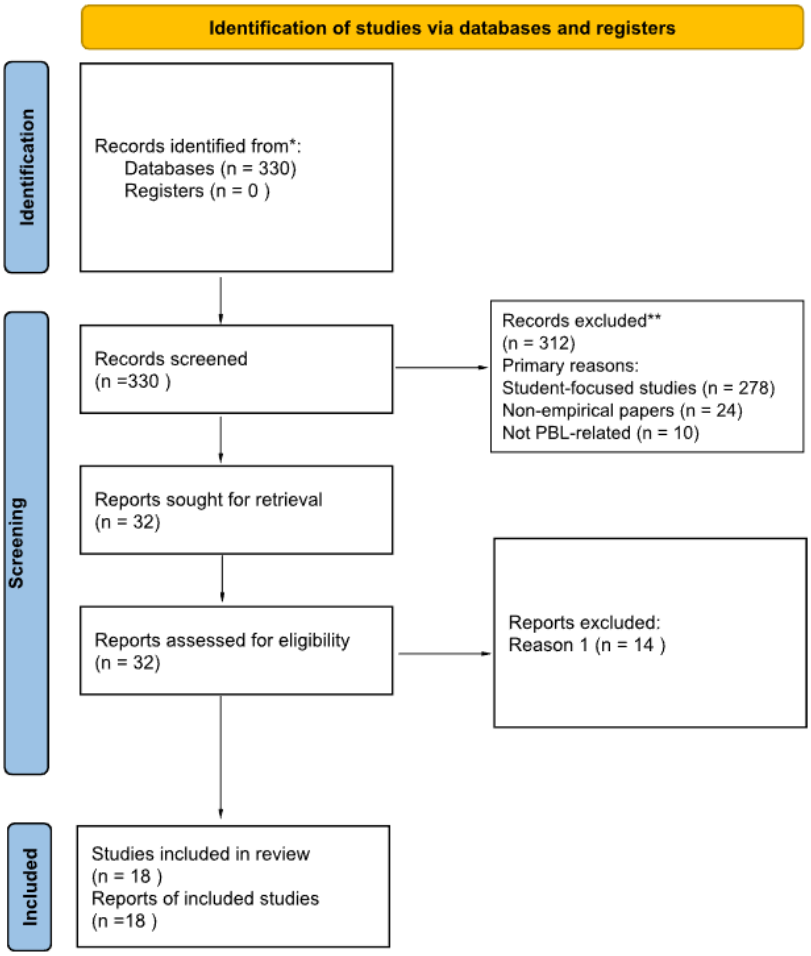
Inclusion Criteria	Exclusion Criteria
Empirical studies employing quantitative, qualitative, or mixed methods designs	Student-focused PBL studies without explicit teacher training emphasis
Focus on K-12 or higher education teacher training programs (preservice or in-service)	Problem-based learning in medical education contexts (different pedagogical approach)
Explicit examination of PBL-specific professional development interventions or training models	Conceptual papers, literature reviews, editorials, or commentaries without primary empirical data
Measurement of teacher-level outcomes (knowledge, beliefs, attitudes, efficacy, practices, or identity)	Studies not accessible in full text despite reasonable efforts to obtain
Published in peer-reviewed English-language journals between 2020-2024	

Study selection followed multi-stage screening conducted by two independent reviewers, with inter-rater reliability assessed using Cohen's kappa ($\kappa = 0.82$), indicating substantial agreement. Data extraction reliability was ensured through: (1) standardized extraction forms pilot-tested on three studies before full implementation, (2) independent extraction by two reviewers with discrepancies resolved through discussion, and (3) consultation with a third reviewer for unresolved disagreements. The final sample comprised 18 empirical studies published between 2020-2024.

PRISMA Flow Diagram

Figure 1 presents the PRISMA flow diagram documenting the study selection process. The diagram illustrates: Initial identification of 330 records through database searching, removal of 312 records during title/abstract screening (278 student-focused studies, 24 non-empirical papers, 10 non-PBL studies), retrieval of 32 full-text articles, and final inclusion of 18 studies after excluding 14 articles (8 lacking explicit training intervention description, 4 insufficient teacher transformation focus, 2 methodological quality concerns).

Figure 1. PRISMA 2020 Flow Diagram for Study Selection Process



Data Analysis

Thematic synthesis followed Braun and Clarke's (2006) six-phase approach: (1) familiarization through repeated reading of included studies, (2) initial coding systematically across all studies identifying training components, transformation dimensions, outcomes, and challenges, (3) theme identification by collating codes into candidate themes, (4) theme review for internal coherence and external distinctiveness, (5) theme definition and naming, and (6) framework construction organizing findings into essential training components, transformation dimensions, success factors, and persistent challenges.

Quality assessment utilized adapted criteria from the Mixed Methods Appraisal Tool (MMAT; Hong et al., 2018) evaluating: (1) research question clarity (clearly stated objectives and phenomena of interest), (2) sampling strategy appropriateness (adequate sample size and sampling method justified for research design), (3) data collection rigor (appropriate

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measurement instruments with reported validity/reliability), (4) analytic approach coherence (systematic analysis procedures clearly described), and (5) conclusion justification (findings supported by data with appropriate acknowledgment of limitations). Each study was rated on a three-point scale (low, moderate, high quality) across applicable criteria. Quality assessment informed result interpretation but did not determine study exclusion, as all included studies met minimum quality thresholds. Inter-rater agreement on quality ratings was substantial (weighted $\kappa = 0.78$).

Bibliometric keyword co-occurrence network analysis was conducted using VOSviewer 1.6.19 software on the broader 330-record corpus, employing: (1) network visualization showing keyword nodes sized by occurrence frequency and colored by thematic cluster, (2) overlay visualization displaying temporal evolution with node colors representing average publication year, and (3) density visualization highlighting research concentration areas. Cluster analysis identified distinct thematic communities using the Louvain algorithm with resolution parameter 1.0. Temporal analysis examined keyword prominence evolution by calculating average publication year for each keyword, identifying emerging versus established research themes.

Results

Study Characteristics

The 18 included studies represented diverse geographical contexts spanning Asian countries (China, Indonesia, Malaysia, Kosovo) and European nations (Spain, Italy). This geographic concentration in Asian and European contexts may limit generalizability to educational systems in Africa, South America, and Oceania, representing an important limitation addressed in the Discussion section. Research designs included case studies, correlational research, phenomenological studies, and mixed methods approaches with sample sizes ranging from 10 to 295 participants. Educational contexts encompassed primary, secondary, and preservice/in-service teacher training, indicating PBL relevance across educational levels. Table 2 presents comprehensive characteristics of all included studies.

Table 2. Study Characteristics Matrix (n=18)

No	Authors (Year)	Country	Research Design	Sample Size	Educational Level	Training Duration/ Format	Key Findings
1	Clark & Shin (2024)	USA	Design Case Study	K-12 novice teachers	K-12	10 weeks, 3 phases: learner → enactor → independent designer	Phase-based design effective; challenges: classroom management, workload, COVID-19 impact
2	Ariyani et al. (2024)	Indone-sia	Correlational descrip-tive	109 primary teachers	Primary	Collaborative work projects (2023)	PBL use influenced by teacher attitudes and efficacy; practical training needed

No	Authors (Year)	Country	Research Design	Sample Size	Educational Level	Training Duration/ Format	Key Findings
3	Zamsis-waya et al. (2024)	Indone-sia	Phenome nological	20 moral theology teachers	Secon-dary (Madra-sah)	In-depth interviews	Islamic identity and behavior enhance PBL methods; significant quality increase
4	Zhao et al. (2023)	China	Multi-case study	2 junior high schools	Secon-dary	Classroom implementation analysis	Alignment gaps between teaching-learning-assessment; teacher engineering knowledge needed
5	Cai et al. (2023)	China	Mixed methods (survey + inter-views)	257 teachers (survey); 10 teachers (inter-views)	Primary	Question-naire & interviews	Positive attitudes toward PBL; training, social support, resources, time positively influence attitudes
6	Jia et al. (2023)	Malaysia	Systemati c literature review	14 journals reviewed	Various	Literature synthesis	DT-PBL enhances creativity and problem-solving; reshapes teacher training paradigms
7	Yánez-Sepúlveda et al. (2023)	Spain	Qualitative (narrated reflection)	53 4th year PE students (13 groups)	Teacher training	Cultural route project development	PBL links content with student motivations; importance of heritage preservation
8	Fang et al. (2023)	China/-USA	Quantitati ve (pre-post survey)	Teachers (4 grade-level groups)	Primary & Seconda ry (Grades 1-9)	5 days (20 hours) online training	Online PD effective; increased PBL knowledge and implementation comfort

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No	Authors (Year)	Country	Research Design	Sample Size	Educational Level	Training Duration/ Format	Key Findings
9	Velasco Moreno (2023)	Spain	Case study	Future FL teachers	Teacher training	2021-22 academic year	PBL brings innovative approaches to FL classes; matches theory and practice
10	Latifaj & Latifaj (2023)	Kosovo	Mixed methods (survey + analysis)	English teachers	Secon-dary	Online survey on ICT-PBL integration	Teachers use ICT moderately; interest in specialized training; PBL not widely used
11	Alromaih et al. (2022)	Saudi Arabia	Mixed methods	40 students (survey); 12 (interviews)	Teacher training (Early childhood)	PBL training in instructional design	Improved design processes; enhanced cognitive, social, emotional skills
12	Molina-Torres (2022)	Spain	Quantitative (survey)	290 Primary Education students	Teacher training (Primary)	Likert scale survey (15 items)	Need for methodological changes; PBL impacts knowledge acquisition in Social Sciences
13	Mamadaliyev et al. (2022)	Kazakhstan	Quantitative	178 special education teachers	Special education	4-week distance education + PBL training	Good use of PBL technology; teachers willing to use in future education
14	Domenici (2022)	Italy	Case study (8-year longitudinal)	171 pre-service chemistry teachers	Teacher training (Chemistry)	STEAM PBL in science museum (8 years)	Non-formal context effective; high student motivation; real-life chemistry topics beneficial
15	Del Barco et al. (2021)	Spain	Qualitative (pre-post	19 prospectiv	Teacher training	Low-cost eco-friendly PBL project	Emotional improvement of teachers;

No	Authors (Year)	Country	Research Design	Sample Size	Educational Level	Training Duration/ Format	Key Findings
			questionnaire)	e primary teachers	(Primary)		sustainability approach effective
16	Javier Aguirregabiria & García-Olalla (2020)	Spain	Didactic research	Primary Education students	Teacher training (Primary)	Interdisciplinary sustainable development project	High quality projects; positive student attitudes; competency development
17	Dogara et al. (2020)	Malaysia	Quantitative (SEM)	295 technical teachers (from 372)	Technical colleges	Survey + CFA/SEM analysis	Preparation, application, commitment, assessment positively impact soft skills integration
18	López et al. (2020)	Ecuador	Mixed methods (field study)	34 teachers; 143 students	Local education	Survey + observation	29% teachers use PBL; 38% students develop critical thinking through PBL

Essential Training Components

Analysis revealed five key components consistently present in effective PBL training programs, representing core elements that collectively address the multifaceted nature of pedagogical role transformation. Table 3 presents frequency, duration, delivery mode, and evidence strength for each component.

Table 3. Essential Training Components Across Included Studies

Training Component	Frequency	Duration Range	Delivery Mode	Evidence
Theoretical Understanding	16/18 (89%)	2-8 hours	Face-to-face, Online, Blended	Strong
Hands-on Practice	15/18 (83%)	4-10 weeks	Primarily face-to-face	Strong
Structured Reflection	14/18 (78%)	Ongoing	All modes	Moderate
Collaborative Learning	13/18 (72%)	Embedded	All modes	Strong
Sustained Mentoring	11/18 (61%)	6 months-1 year	Face-to-face, Hybrid	Strong

Theoretical understanding emerged as the most prevalent component (89%), encompassing foundational knowledge of PBL principles, pedagogical rationale, and conceptual frameworks providing teachers with essential conceptual grounding for role transformation. Hands-on practice followed closely (83%), requiring 4-10 weeks for teachers to implement actual PBL projects with students in authentic classroom contexts. Sustained mentoring,

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present in 61% of studies and extending 6 months to 1 year, indicates that teacher transformation requires ongoing support beyond initial workshops, addressing the complex process of professional identity reconstruction.

Teacher Transformation Dimensions

Teacher transformation progressed across three interrelated dimensions demonstrating the multidimensional nature of role change encompassing cognitive, affective, and behavioral domains. Table 4 presents the developmental trajectory from pre-training to post-training conditions.

Table 4. Three Dimensions of Teacher Transformation Through PBL Training

Dimension	Pre-Training	Post-Training	Assessment Tools	Studies
Pedagogical Competence	Limited PBL knowledge; teacher-centered approaches	Understanding PBL principles; student-centered orientation	Knowledge tests, Design rubrics	16
Teaching Self-Efficacy	Doubt in facilitating student-directed learning	High confidence; positive attitudes toward PBL	Attitude surveys, Efficacy scales	12
Classroom Implementation Skills	Difficulty managing project complexity	Well-organized implementation; effective facilitation	Observation protocols, Implementation checklists	10

These three dimensions demonstrate interdependent rather than sequential development, with growth in pedagogical competence supporting increased self-efficacy, which in turn enables more effective classroom implementation. For example, as teachers gained deeper understanding of PBL principles (competence), their confidence in facilitating student-directed learning increased (efficacy), enabling them to manage project complexity more effectively (implementation). This interconnection suggests training programs must address all three dimensions simultaneously rather than treating them as separate outcomes.

Pedagogical competence development, documented in 16 studies, encompassed shifts from limited PBL knowledge and teacher-centered approaches to deep understanding of PBL principles and student-centered orientation. Teaching self-efficacy shifts, measured in 12 studies through attitude surveys and efficacy scales, reflected transformation from doubt in facilitating student-directed learning to high confidence and positive attitudes toward PBL (Ariyani et al., 2024). Classroom implementation skills, observed in 10 studies using observation protocols and implementation checklists, involved progression from difficulty managing project complexity to well-organized implementation and effective facilitation.

Implementation Barriers

Despite training interventions, persistent implementation challenges emerged across technical, political, and cultural dimensions, representing systemic obstacles requiring coordinated support strategies beyond individual teacher development. Table 5 presents the framework of barriers organized by type with corresponding support strategies.

Table 5. Implementation Barriers Framework (Technical-Political-Cultural)

Barrier Type	Specific Challenge	Frequency	Support Strategy
Technical	Classroom Management Complexity	14/18 (78%)	Embedded management training, Modeling, Extended practice
	Time-Intensive Planning	13/18 (72%)	Planning time allocation, Project templates
Political	Curriculum Standards Alignment	12/18 (67%)	Standards mapping tools, Backward design
	Limited Resources & Materials	11/18 (61%)	Resource allocation advocacy, Low-cost design
Cultural	Beliefs About Knowledge Transmission	8/18 (44%)	Identity transformation support, Success stories

Technical barriers dominated with classroom management complexity reported in 78% of studies and time-intensive planning requirements in 72%. Political challenges included curriculum standards alignment difficulties (67%) and limited resources (61%). Cultural barriers manifested as deeply held beliefs about knowledge transmission (44%), requiring extended support for pedagogical identity transformation (Clark & Shin, 2024; Zamsiswaya et al., 2024).

Bibliometric Network Analysis

VOSviewer analysis of 330 articles revealed three main thematic clusters representing distinct research communities and demonstrating the field's evolution from foundational pedagogical research toward technology-enhanced implementation solutions. Table 6 presents cluster characteristics including core keywords, size, temporal patterns, citation impact, and interconnectivity.

Table 6. Bibliometric Cluster Characteristics (VOSviewer Analysis, n=330)

Cluster	Core Keywords	Size	Avg Pub Year	Avg Citations	Link Strength
Cluster 1: Pedagogical Innovation	Project-based learning, Active learning, Collaborative learning, Experiential learning	87	2021.2-2021.8	10.8	High
Cluster 2: Professional Development	Teacher training, Teacher education, Professional development, Curriculum design	124	2021.8-2022.2	8.1	Very High
Cluster 3: Technology Integration	Artificial intelligence, Digital technologies, E-learning, COVID-19	119	2022.3-2023.0	15.4	High

Cluster 1 (Pedagogical Innovation) contained 87 keywords focusing on theoretical foundations with average publication year 2021.2-2021.8, representing established PBL

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theoretical frameworks and pedagogical principles. This cluster's connection to teacher training research demonstrates how foundational PBL theory informs professional development design.

Cluster 2 (Professional Development) emerged as the largest cluster with 124 keywords and very high interconnectivity, covering teacher training and curriculum design. The cluster's central position and high link strength indicate its role as the primary bridge connecting pedagogical theory (Cluster 1) with technological innovation (Cluster 3), positioning teacher professional development at the nexus of theoretical foundations and emerging practice.

Cluster 3 (Technology Integration) comprised 119 keywords representing the most recent frontier (average publication year 2022.3-2023.0) with highest average citations (15.4), featuring artificial intelligence, digital technologies, and COVID-19 impacts. Temporal patterns show research evolution from pedagogical foundations toward technology integration, with COVID-19 acting as catalytic node accelerating digital transformation and AI representing the newest high-impact frontier (Jia et al., 2023). This cluster's high citation impact suggests strong scholarly interest in technology-enhanced solutions to persistent teacher training challenges.

The bibliometric positioning reveals that PBL teacher transformation research occupies a strategic convergence point where pedagogical innovation, professional development theory, and technological integration intersect, with COVID-19 serving as an accelerator of digital transformation and AI emerging as the most promising frontier for scalable, sustained teacher support.

Discussion

The findings align with adult learning theory and professional identity development frameworks, demonstrating that teacher transformation requires integrated development addressing cognitive understanding, affective disposition, and behavioral implementation simultaneously. The prevalence of theoretical understanding (89%) combined with hands-on practice (83%) reflects the theory-practice integration principle emphasized in teacher education literature, supporting Knowles' (1984) andragogy principle that adults learn best when they understand both the rationale for new knowledge and have opportunities to apply it in authentic contexts.

The five essential training components function synergistically rather than independently. Theoretical understanding provides the conceptual foundation enabling teachers to make sense of their hands-on practice experiences. Structured reflection transforms these experiences into learning by prompting critical examination of assumptions. Collaborative learning creates communities of practice where teachers construct collective knowledge and receive peer support. Sustained mentoring extends this support beyond initial training, addressing the extended timeline required for professional identity reconstruction. This integrated model suggests that effective programs must embed all five components within coherent, long-term developmental processes rather than treating them as optional or sequential add-ons.

The three transformation dimensions demonstrate clear interdependence. Pedagogical competence development (understanding PBL principles and student-centered orientation) establishes the knowledge foundation supporting increased teaching self-efficacy (confidence in facilitating student-directed learning). This enhanced self-efficacy, in turn, enables teachers to develop classroom implementation skills (managing project complexity and effective facilitation). However, the relationship is reciprocal rather than linear—successful implementation experiences reinforce self-efficacy and deepen pedagogical understanding. This reciprocal reinforcement explains why programs providing authentic practice opportunities within supportive environments demonstrate stronger transformation outcomes.

The high frequency of classroom management challenges (78%) underscores the complexity of transitioning from traditional to student-centered pedagogy, where teachers must develop new skills in facilitating autonomous learning rather than controlling classroom activities. This finding supports transformative learning theory's emphasis on disorienting dilemmas that prompt critical examination of pedagogical beliefs (Mezirow, 1997, 2000), suggesting that effective training must explicitly address these dilemmas through modeling, extended practice, and community support rather than assuming teachers will naturally overcome them.

The bibliometric analysis revealed temporal evolution from foundational pedagogical research (2021.2-2021.8) through professional development emphasis (2021.8-2022.2) to technology integration frontier (2022.3-2023.0), suggesting the field is moving beyond establishing PBL's theoretical foundations toward addressing practical implementation challenges through technology-enhanced solutions. The positioning of COVID-19 as a catalytic network node confirms the pandemic's role in accelerating digital transformation, while AI's emergence as the highest-impact frontier suggests potential for scalable solutions to the sustained mentoring challenge identified across studies.

These findings corroborate and extend previous research on PBL teacher training. The five essential components identified align with Darling-Hammond et al.'s (2017) principles of effective professional development, including content focus, active learning, coherence, duration, and collective participation. However, this study specifically articulates how these components facilitate the particular transformation from instructor to facilitator roles, adding specificity to generic professional development frameworks by demonstrating that instructor-to-facilitator transformation requires more than skill acquisition—it demands fundamental reconceptualization of professional identity.

The three-dimensional transformation model extends Beijaard et al.'s (2004) conceptualizations by explicitly linking pedagogical competence, self-efficacy, and implementation skills as interdependent rather than separate outcomes. While previous research often treated these as distinct variables to be developed independently, our synthesis demonstrates they function as interconnected components of a unified transformation process. This integration provides a more nuanced understanding of how teacher change occurs and suggests assessment approaches should evaluate transformation holistically rather than measuring isolated competencies.

The persistent implementation barriers identified mirror challenges documented in broader educational change literature (e.g., Fullan, 2007), confirming that structural and cultural factors significantly influence pedagogical innovation adoption regardless of individual teacher capacity. This alignment across contexts suggests that barriers to PBL implementation are not unique to specific settings but represent universal challenges requiring systemic solutions including institutional commitment, resource allocation, and cultural change strategies.

The bibliometric finding of COVID-19 as a catalytic network node confirms other analyses showing pandemic-driven acceleration of digital transformation in teacher professional development (Trust & Whalen, 2020). The emergence of artificial intelligence as the newest high-impact frontier represents a novel contribution, suggesting AI-powered tools may offer scalable solutions to sustained mentoring challenges identified across studies (Holmes et al., 2019), though research is needed to validate their effectiveness compared to traditional mentoring approaches.

For educational practice, findings suggest effective PBL implementation requires systemic support structures rather than isolated training events. Professional development programs should be designed as long-term developmental processes spanning 6-12 months with embedded mentoring components, integrating all five essential components: theoretical

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understanding providing conceptual foundation (2-8 hours), hands-on practice enabling authentic application (4-10 weeks), structured reflection prompting critical examination (ongoing), collaborative learning creating peer support networks (embedded throughout), and sustained mentoring extending support beyond initial training (6 months-1 year).

Training designs must create authentic practice opportunities where teachers can experiment with facilitation roles in low-stakes environments before high-stakes classroom implementation. This might include practice-teaching with peer groups, implementing pilot projects with small student groups, or co-facilitating projects with experienced PBL teachers, allowing teachers to develop facilitation skills while receiving real-time feedback and support.

For policy, findings indicate need for institutional commitment including: (1) dedicated planning time allocation addressing the time-intensive nature of project design, (2) resource provision ensuring access to materials and technologies needed for project implementation, (3) standards mapping tools facilitating curriculum alignment, and (4) protected collaboration time enabling peer learning communities. Without these institutional supports, even well-trained teachers struggle to implement PBL effectively given persistent technical and political barriers.

For research, the SLNA methodology demonstrates value in revealing both empirical evidence and scholarly positioning, suggesting integrated approaches can advance understanding of educational phenomena beyond what systematic review or bibliometric analysis achieves independently. The identification of AI as emerging frontier suggests research priorities for investigating: (1) AI-powered personalized learning pathways for teacher development, (2) virtual reality simulations for practicing facilitation skills, (3) online professional learning networks for sustained peer support, and (4) automated feedback systems for project design improvement.

This review has several limitations warranting consideration: Geographic concentration: The predominance of studies from Asian and European contexts limits generalizability to educational systems in Africa, South America, and Oceania. Different cultural values regarding teacher authority, student autonomy, and knowledge construction may influence both training effectiveness and implementation challenges in these underrepresented regions.

Methodological constraints: The predominance of case studies and small-sample correlational designs (n=10-295) constrains causal inference about training effectiveness. While these designs provide rich contextual understanding, they limit conclusions about which specific training components or combinations produce optimal transformation outcomes across diverse settings.

Publication bias: The review may overestimate program effectiveness by excluding unsuccessful training programs or negative findings unlikely to be published. This “file drawer problem” is particularly relevant for professional development research where positive results are more publishable than null findings. Self-reported measures: The synthesis relied primarily on self-reported measures of transformation (attitude surveys, self-efficacy scales) rather than objective observation of classroom practice changes, which may inflate perceived transformation effects due to social desirability bias or lack of awareness of one’s actual practice.

Temporal confounding: The review period (2020-2024) coincided with COVID-19 disruptions, potentially confounding findings with pandemic-related adaptations. For example, increased online professional development adoption may reflect emergency responses rather than evidence-based practice, and reported implementation challenges may partly stem from pandemic-related stress and resource constraints. Assessment heterogeneity: The heterogeneity in training duration, delivery modes, and assessment tools across studies

complicated direct comparison and synthesis of outcomes. Without standardized measures, determining which program configurations produce superior results remains challenging.

Bibliometric analysis limitations: The bibliometric component faces limitations inherent to keyword-based analysis including: (1) dependence on author-selected keywords which may not capture all relevant themes, (2) Scopus database bias toward English-language publications potentially missing important non-English research, and (3) co-occurrence networks reflecting publication patterns rather than actual conceptual relationships.

Several research priorities emerge from this synthesis:

Longitudinal experimental studies: Research should employ experimental or quasi-experimental designs with larger samples tracking teacher transformation trajectories over extended periods (2-5 years post-training) to identify factors that sustain or erode pedagogical change over time. Such studies could randomly assign teachers to different program configurations (e.g., varying mentoring duration, practice intensity, or theoretical depth) enabling causal claims about optimal training components and their long-term effectiveness.

Comparative effectiveness research: Studies should systematically evaluate different training components and delivery models to determine optimal program configurations for diverse contexts. For example, comparing outcomes between programs with varying ratios of theoretical instruction to hands-on practice, or investigating whether face-to-face mentoring produces better results than technology-mediated support, would provide actionable guidance for program design.

Technology-enhanced mentoring: Given bibliometric evidence positioning technology integration as an emerging frontier, research should investigate AI-powered tools, virtual reality simulations, and online professional learning networks as potential solutions for scalable, sustained support. Specific investigations might examine: (1) effectiveness of AI chatbots providing on-demand pedagogical guidance compared to scheduled human mentoring, (2) VR simulations of challenging classroom scenarios for developing facilitation skills, and (3) online communities of practice for sustaining peer support beyond formal training periods.

Cross-cultural comparative studies: Comparing PBL training effectiveness across diverse educational systems would enhance understanding of cultural factors that facilitate or inhibit teacher transformation. Such research should examine how cultural values regarding teacher authority, student autonomy, and knowledge construction influence both training design requirements and implementation outcomes.

Objective outcome measures: Research should move beyond self-reported measures to include classroom observation protocols documenting actual practice changes, student learning outcomes demonstrating teaching effectiveness, and long-term retention rates showing sustained implementation. Multi-method approaches combining self-report surveys, classroom observations, student work analysis, and student achievement data would provide more robust evidence of training impact.

Conclusion

This systematic literature review provides compelling evidence that well-designed PBL training programs can effectively facilitate teacher transformation from traditional instructors to student-centered facilitators. Five essential components must be integrated: theoretical understanding, hands-on practice, structured reflection, collaborative learning, and sustained mentoring. Three transformation dimensions develop interdependently: pedagogical competence, teaching self-efficacy, and classroom implementation skills. While persistent challenges in classroom management, time allocation, and resource constraints remain

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significant barriers, evidence suggests these can be mitigated through systematic support structures, institutional commitment, and long-term developmental approaches spanning 6-12 months.

The integrated SLNA methodology demonstrated value in revealing both empirical evidence and scholarly positioning at the intersection of pedagogical innovation, professional development theory, and technological integration. As the field evolves toward technology-enhanced solutions, with artificial intelligence representing the most recent high-impact frontier, future research and practice must balance innovation with fundamental human elements of mentoring and professional community that emerged as critical success factors.

Ultimately, sustainable PBL implementation depends not merely on training individual teachers but on cultivating systemic conditions that support ongoing pedagogical transformation as a career-long professional journey, including institutional commitment to planning time, resource allocation, and collaborative professional learning communities.

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