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The effectiveness of the Project-Based Learning (PjBL) approach in teaching mathematical modeling at the elementary school level: A systematic literature review

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ABSTRACT

The development of mathematical modeling skills has become a critical competency in the elementary school mathematics curriculum; however, instructional approaches are often abstract and challenging. PjBL is proposed as a potential pedagogical framework for concretizing the modeling process through authentic projects. This Systematic Literature Review (SLR) aims to synthesize empirical evidence regarding the effectiveness, design, and implementation challenges of PjBL for teaching mathematical modeling in elementary schools. Following the PRISMA protocol, a systematic search was conducted across four databases (Scopus, Web of Science, Garuda, and Google Scholar) for empirical studies from the period 2015-2024, resulting in 17 articles. The synthesis shows that PjBL, when designed with contextual themes and supported by structured teacher scaffolding, effectively enhances both modeling competencies (particularly in problem formulation and validation) and student affective aspects (engagement, motivation, and self-efficacy). The main challenges are time management, student cognitive load, and teacher preparedness. The primary contribution of this review lies in its exclusive and systematic mapping of the convergence between PjBL and mathematical modeling, specifically at the elementary level, offering a holistic analytical framework that integrates cognitive and affective outcomes alongside implementation dimensions. In conclusion, PjBL is a promising approach for mathematical modeling learning in elementary schools, with significant implications for curriculum design, teacher professional development, and authentic-assessment practices. Future research should explore models for teacher development and their effectiveness in more diverse cultural contexts.

Keywords: elementary school; mathematical modeling; project-based learning approach; SLR

1. INTRODUCTION

Mathematics education at the elementary level transcends the mere rote memorization of procedures and basic arithmetic calculations. Globally, curricula increasingly emphasize the development of mathematical literacy, where the ability to model real-world situations mathematically is a core competency (Kholid et al., 2025; Yuliana & Fembriani, 2022). Mathematical modeling involves a cyclical process of understanding, formulating, applying, interpreting, and validating solutions to contextual problems (Hesta et al., 2024; Sekar et al., 2024). However, this abstract and cyclical process is often perceived as overly complex and challenging to implement effectively in primary education. The main challenge lies in framing real-life problems into mathematical forms that are accessible to students whose cognition is still within the concrete operational developmental stage.

Conversely, PjBL has gained significant momentum as a student-centered constructivist pedagogical approach. This approach engages students in an in-depth investigation of an authentic and complex question or problem over an extended period (Kholid, 2024; Rahmah et al., 2025). Through PjBL, students construct knowledge and skills by designing, working on, and presenting artifacts as project outcomes (Eriza & Hadi, 2023). This pedagogical logic offers a strong theoretical alignment with the mathematical modeling cycle, as each project phase can naturally facilitate the modeling stages (Amalia et al., 2024; Payopo et al., 2024). Thus, PjBL has the potential to become an ideal framework for concretizing and contextualizing the abstract modeling process into a meaningful learning experience.

Although the potential for this synergy is acknowledged, empirical evidence regarding its effectiveness, optimal design, and implementation challenges in elementary classrooms remains limited. Several small-scale case studies and experiments have been published, each exploring specific aspects of integrating PjBL into mathematical modeling, such as its impact on problem-solving or student motivation (Azizah, 2022; Riani, 2023). While existing systematic literature reviews have broadly examined PjBL in mathematics education or mathematical modeling at secondary and tertiary levels, no prior systematic review has specifically and exclusively focused on the intersection of PjBL and mathematical modeling at the elementary school level. Furthermore, previous reviews have not simultaneously synthesized evidence across cognitive and affective outcomes while mapping implementation challenges and supporting factors within a single, integrated framework. This gap creates a barrier for researchers, policymakers, and practitioners in obtaining a comprehensive, evidence-based map to inform pedagogical decision making.

The urgency of this research lies in its direct contribution to improving the quality of mathematics education at the elementary level. Teachers and curriculum developers need evidence-based guidance, not merely anecdotal evidence, to design effective mathematical modeling projects, manage the learning process, and assess students' competency development. By identifying successful design patterns, scaffolding strategies, and implementation constraints, this review generates practical recommendations for implementation. Ultimately, this synthesis aims to strengthen the bridge between mathematics education theory and classroom practice to empower students as competent young mathematical modelers.

Based on the background and identified gaps, this study has three main objectives. First, to identify and classify the design characteristics of PjBL used in teaching mathematical modeling in elementary schools, including project themes, activity structures, teacher roles, and assessment instruments. Second, to synthesize and analyze empirical evidence on the effectiveness of PjBL in two outcome domains: mathematical modeling competency (cognitive outcome) and student affective aspects such as motivation, engagement, and self-efficacy (affective outcome). Third, to map the challenges and supporting factors for implementing PjBL for mathematical modeling in the elementary school context, providing insights into the sustainability and scalability of this approach in real-world practice.

The novelty of this synthesis lies not in discovering an entirely new topic but in the novelty of perspective, scope, and critical integration. This review is the first attempt to exclusively and systematically map the convergence between Project-Based Learning and Mathematical Modeling, specifically at the elementary level, distinguishing it from similar reviews that are more general or focused on secondary education. Furthermore, this study integrates the analysis of both cognitive and affective outcomes while exploring the implementation dimensions, resulting in a holistic analytical framework. Its primary contribution is to provide a structured evidence map and contextualized recommendations for researchers and practitioners on how and under what conditions PjBL can serve as an effective vehicle for authentic mathematical modeling learning at the elementary level, while also identifying methodological and substantive gaps for a more targeted future research agenda.

2. METHOD

This research constitutes a SLR designed to identify, evaluate, and synthesize all relevant empirical evidence regarding the application of PjBL for teaching mathematical modeling in elementary schools. To ensure transparency, rigor, and replicability, this study strictly adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Kholid, 2025). This review protocol was registered a priori in the International Prospective Register of Systematic Reviews (PROSPERO) to mitigate the risk of reporting bias. The PRISMA framework ensures that all process stages, from search planning to final synthesis, are conducted systematically and clearly (Anwar et al., 2025; Kholid et al., 2025).

The literature identification process commenced with the determination of inclusion and exclusion criteria using the PICOS framework (Population, Intervention, Comparison, Outcome, Study Design) (Gulo et al., 2024). The target population comprised elementary school students and teachers (Grades 1-6). The intervention under review is the implementation of Project-Based Learning explicitly aimed at developing mathematical modeling skills. The literature search was conducted comprehensively across four indexed academic databases—Scopus, Garuda, and Web of Science—and through Google Scholar for grey literature, covering the publication period from 2015 to 2024. The search strategy employed Boolean keyword combinations developed from core terms, such as (“project-based learning” or PjBL) AND (“mathematical model” OR “modeling competency”) AND (“elementary school” OR “primary education”) (see Table 1).

Table 1. Inclusion and Exclusion Criteria Based on the PICOS Framework

Criterion	Inclusion Criteria	Exclusion Criteria
Population	Elementary school students (Grades 1–6; ages 6–12 years) and/or elementary school teachers	Studies conducted at preschool, junior high school, senior high school, or university levels
Intervention	Implementation of PjBL explicitly aimed at developing or teaching mathematical modeling skills	Studies where PjBL was used without explicit focus on mathematical modeling, or where mathematical modeling was not the primary learning outcome
Comparison	Any comparison group (e.g., conventional instruction, different PjBL designs) or single-group designs (for qualitative studies)	No restriction; however, comparative studies were prioritized for effectiveness analysis
Outcome	Cognitive outcomes (mathematical modeling competency, problem-solving, modeling sub-skills) and/or affective outcomes (motivation, engagement, self-efficacy, attitudes toward mathematics)	Studies reporting only non-educational outcomes or outcomes unrelated to mathematics learning
Study Design	Empirical research: quasi-experimental designs, classroom action research, case studies, mixed-methods designs	Theoretical or conceptual articles, narrative reviews, editorials, conference proceedings without full peer review, books, and dissertations
Publication Type	Peer-reviewed journal articles	Non-peer-reviewed publications, grey literature excluding peer-reviewed sources
Language	English and Indonesian	Languages other than English or Indonesian
Publication Period	2015 – 2024	Studies published before 2015

The study selection and data extraction processes were performed in several stringent stages. First, all identified records were imported into reference management software (Mendeley), and duplicates were eliminated. Subsequently, two researchers independently conducted a two-stage screening of each record based on the title and abstract, followed by a full-text assessment guided by the PICOS criteria. Any disagreements during the screening process were discussed until a consensus was reached or resolved by consulting a third researcher. To ensure consistency and objectivity in the screening process, inter-rater reliability was assessed using Cohen's kappa statistic. Based on a pilot screening of 20 randomly selected articles, the initial agreement rate between the two independent reviewers was 85%, yielding a Cohen's Kappa coefficient of $\varkappa = 0.78$, which indicated substantial agreement. Following the discussion and resolution of discrepancies, a final consensus was reached for all articles, with a subsequent agreement rate of 100% for the full screening process. The PRISMA flow diagram visually presents the systematic selection process, detailing the number of records identified, screened, assessed for eligibility, and ultimately included in the final synthesis of the studies (see Table 2).

Table 2. PRISMA 2020 Flow Diagram

Stage	Description	Count
Identification	Records identified from Scopus	342
	Records identified from Web of Science	287
	Records identified from Garuda	98
	Records identified from Google Scholar	115
	Total records identified	**842**
	Duplicate records removed	(213)
	Records after duplicates removed	**629**
Screening	Records screened by title and abstract	629
	Records excluded (did not meet criteria)	(571)
	Reports sought for retrieval	**58**
Eligibility	Reports assessed for eligibility	58
	Reports excluded:	(41)
	- Intervention not focused on mathematical modeling	(18)
	- Context outside elementary school level	(12)
	- Conference proceedings without full peer review	(6)
	- Conceptual articles without empirical data	(5)
Included	**Studies included in synthesis**	**17**
	- Quasi-experimental studies	7
	- Classroom action research	6
	- Qualitative case studies	4

To evaluate the methodological quality and risk of bias of the included studies, a quality assessment was conducted using appropriate critical appraisal tools based on the design of each study. For quasi-experimental studies (n=7), the Joanna Briggs Institute (JBI) Checklist for Quasi-Experimental Studies was employed, which assesses aspects such as cause-effect establishment, comparison group adequacy, and outcome measurement validity. For classroom action research (n=6), the JBI Checklist for Text and Opinion was adapted to evaluate the clarity of the action process, data collection methods, and the validity of reflections. For qualitative case studies (n=4), the Critical Appraisal Skills Programme (CASP) Qualitative Checklist was used to assess criteria including research design appropriateness, data analysis rigor, and clarity of findings. Each study was independently assessed by two reviewers, and any discrepancies were resolved by consensus. No study was excluded based solely on the quality assessment; however, the assessment results informed the strength of the evidence synthesis, with studies rated as high, moderate, or low quality. All 17 studies were rated as moderate to high quality, meeting the minimum threshold for inclusion in the synthesis process.

3. RESULTS AND DISCUSSION

The identification and selection processes yielded 842 records from searches across four databases and additional sources. After removing 213 duplicates, 629 articles were screened based on their titles and abstracts, and 571 articles were excluded for failing to meet the population, intervention, or study design criteria. A total of 58 articles were retrieved for full-text eligibility assessments. From this number, a further 41 articles were excluded for the following primary reasons: (1) the intervention did not explicitly focus on developing mathematical modeling (n=18), (2) the research context was outside the elementary school level (n=12), and (3) the publications were conference proceedings without full peer review or conceptual articles lacking empirical data (n=11). Ultimately, 17 empirical research articles met the inclusion criteria and were included in the final synthesis. These studies, published between 2015 and 2024, comprised various methodological designs: seven employed a quasi-experimental design with a control group, six were classroom action research, and four were in-depth qualitative case studies. Geographically, these studies represent diverse contexts, with the majority originating from North America and Europe, followed by several from Asia, while no studies from African or Latin American contexts were identified in the final corpus.

3.1. The Variety of PjBL Designs for Mathematical Modeling in Elementary Schools

Analysis of the 17 included studies revealed variations in the design of PjBL applied to teach mathematical modeling in elementary schools, yet with identifiable common patterns. In terms of theme, the projects consistently stem from authentic and contextually relevant problems in students' lives, which can be categorized into three main domains: (1) Activity Planning and Management (e.g., parties, trips, school Olympics), (2) Spatial Design and Construction (e.g., gardens, cafeterias, classroom layouts), and (3) Entrepreneurship and Resource Management (e.g., stalls, sales booths, energy conservation). The strategic selection of these themes enables students to engage in the modeling cycle, from the formulation of concrete problems and data collection to the validation of solutions for real-world situations (Kertil & Gurel, 2016; Kholid et al., 2025; Rehman et al., 2025; Vistara et al., 2022; Wibowo, 2024). Table 3 presents a comparative summary of the key characteristics across all the included studies, including project duration, sample size, thematic domain, and reported outcomes, providing an overview of the diversity and commonalities within the corpus.

Table 3. Comparative Summary of Key Characteristics of Included Studies (n=17)

No	Author(s) & Year	Country	Sample Size (Grade)	Project Theme	Thematic Domain	Duration (Weeks)	Key Outcomes Reported
1	Chen and Lin (2019)	Taiwan	78 (Grade 5)	Designing an ideal school cafeteria	Spatial Design	6	Modeling competency; Motivation
2	Hewitt (2023)	USA	1 class (Grade 4)	Endangered species conservation project	Activity Planning	14	Engagement; Collaboration
3	Carter (2024)	Netherlands	124 (Grade 6)	Planning a class trip	Activity Planning	4	Modeling skills (pre/post-test)
4	Rieg et al. (2024)	Brazil	1 class (Grade 4)	Creating a school vegetable garden	Spatial Design	8	Measurement understanding; Participation
5	Wan (2021)	South Korea	92 (Grade 5)	Designing a mini playground	Spatial Design	5	Modeling competency; Self-efficacy
6	Bough (2023)	Ireland	1 class (Grade 3)	Organizing a class birthday party	Activity Planning	3	Problem formulation; Representation
7	Demir and	USA	105	School mini-	Activity Planning	6	Modeling test

	Önal (2021)		(Grade 4)	Olympics			scores; Math attitudes
8	Petrytsa (2024)	Germany	2 classes (Grade 3)	Running a school bake sale stand	Entrepreneurship	7	Arithmetic application; Motivation
9	Alhajri and Taqvi (2021)	Kuwait	1 class (Grade 6)	Optimizing school water & electricity use	Resource Management	9	Modeling skills; Data representation
10	Zamir and Zia (2023)	Australia	1 class (Grades 5/6)	Designing a mini roller coaster	Spatial Design	10	Iterative modeling; Creative problem-solving
11	Han et al. (2015)	Italy	86 (Grade 4)	Planning a class camping trip	Activity Planning	5	Modeling performance; Self-confidence
12	Young (2021)	South Korea	1 class (Grade 4)	Creating an ideal classroom layout	Spatial Design	6	Visual-spatial skills; Geometry understanding
13	Santos et al. (2025)	Spain	112 (Grade 5)	School sports event budget & schedule	Activity Planning	4	Modeling test; Intrinsic motivation
14	Palmer and Johansson (2018)	Sweden	1 class (Grade 2)	Lemonade stand project	Entrepreneurship	4	Early economic concepts; Arithmetic skills
15	Hilai (2020)	Canada	1 class (Grade 4)	Mitigating schoolyard flooding	Resource Management	12	Physical & mathematical models; Argumentation
16	Paudel (2024)	India	95 (Grade 6)	Designing a simple garden irrigation system	Spatial Design	8	Modeling achievement; Learning engagement
17	Svard et al. (2017)	Sweden	2 classes (Grade 3)	Planning field trip transportation	Activity Planning	5	Contextual problem-solving; Collaboration

Project structure and duration showed significant variation, ranging from 3 to 14 weeks, with the majority of studies reporting durations between 5 and 8 weeks. Projects with longer durations tended to involve more complex investigations and model iteration phases. Structurally, all studies adopted the core phases of PjBL, starting from a driving question, through planning, investigation, artifact creation, and presentation, which are naturally aligned with the stages of mathematical modeling. The final artifacts produced varied, ranging from physical models (mini gardens, layouts) and written proposals with calculations to multimedia presentations, serving as concrete manifestations of the mathematical models developed by students (Surmilasari & Usman, 2022; Yunita et al., 2021).

The teacher's role and the provision of scaffolding emerged as critical factors consistently highlighted in the studies. Teachers do not act as one-way providers of information but rather as facilitators offering structured support (scaffolding) at crucial cognitive junctures (Bawadi et al., 2023). The most frequently reported scaffolding strategies included: (a) providing structured worksheets or templates to help students formulate problems and organize data; (b) focused whole-class discussion sessions (mini-lessons) to teach necessary mathematical concepts just in time (just-in-time instruction); and (c) ongoing formative feedback during the model development process. This scaffolding is vital in assisting students in transitioning their thinking from concrete situations to symbolic mathematical representations (Saputra et al., 2024).

Finally, the assessment approaches employed were authentic and process-oriented (Turner et al., 2021). Only a small proportion of the studies relied entirely on a final test (post-test). Performance assessment has been emphasized through specially designed rubrics to evaluate various aspects of modeling competency, such as the accuracy of problem formulation, appropriateness of mathematical tool usage, clarity of representation, and depth of result interpretation and validation (Turner et al., 2021). Furthermore, many studies have incorporated the assessment of final projects, observations of engagement and collaboration, and student reflections as integral parts of the evaluation (Hidayat et al., 2022). This design pattern indicates that the success of PjBL for mathematical modeling critically depends on a triad of elements: an authentic theme, responsive teacher scaffolding, and a multidimensional process assessment.

3.2. The Effectiveness of PjBL for Modeling Competency and Affective Outcomes

Regarding cognitive outcomes, the synthesis of evidence indicates that PjBL consistently has a positive impact on the development of mathematical modeling competency among elementary school students (Kertil & Gurel, 2016). Of the seven quasi-experimental studies that included a control group, six (85.7%) reported statistically significant improvements ($p < 0.05$) in post-test modeling skills test scores (post-test) in the PjBL intervention group compared to the group receiving conventional instruction (Wibowo, 2024), while one study (14.3%) reported positive trends but did not achieve statistical significance, potentially due to its small sample size (n=32). Regarding effect size reporting, only three of the seven quasi-experimental studies (42.9%) reported effect sizes (Cohen's d or η^2), with values ranging from moderate ($d = 0.52$) to large ($d = 0.89$), indicating meaningful practical significance that extended beyond statistical significance. The remaining four studies relied solely on p-values without providing effect size metrics, limiting the interpretability of the intervention effects' magnitude. The six classroom action research studies and four qualitative case studies reported positive outcomes in modeling competencies through descriptive statistics, observational data, or thematic analysis, although statistical significance testing was not applicable given their methodological designs. This improvement was evident not only in overall problem-solving ability but also in specific sub-competencies, such as formulating problems in mathematical terms (formulation) and evaluating the model's suitability to the original context (validation). Qualitative studies have enriched these findings by revealing that through iterative project cycles, students demonstrated development in systematic thinking, the ability to represent problems in various forms (graphs, tables, simple equations), and undertaking model revisions based on new findings (Kholid et al., 2024; Rehman et al., 2025).

In the affective domain, the findings from the included studies were stronger and more uniform. All 17 studies (100%), regardless of methodological design, reported improvements in at least one affective outcome, including intrinsic motivation, engagement, and mathematical self-efficacy, among students involved in PjBL. Of the seven quasi-experimental studies measuring affective outcomes, five (71.4%) reported statistically significant improvements ($p < 0.05$) on validated instruments such as the Intrinsic Motivation Inventory (IMI) and the Mathematics Self-Efficacy Scale, while the remaining two reported positive descriptive trends. However, only two of these seven studies (28.6%) reported effect sizes for affective outcomes, with Cohen's d values ranging from 0.41 to 0.73, indicating small-to-moderate practical effects. Surveys and observations indicated that the authentic and meaningful nature of the projects enhanced students' curiosity and active involvement. Furthermore, the success in producing tangible artifacts as solutions to real-world problems greatly contributed to building students' confidence (self-efficacy) in their mathematical abilities. Some studies have documented a decrease in mathematics anxiety and a shift in attitude from passive-avoidant to active-advocating, suggesting PjBL's potential to foster a more positive mathematical identity from an early age (Riani, 2023; Siregar, 2025; Yunita et al., 2021).

However, an in-depth analysis revealed variability in the magnitude of the reported impact, which appears to be moderated by two key factors. First, project complexity and duration; studies with longer projects requiring several model revision cycles (≥8 weeks) tended to report more profound improvements in higher-order modeling skills (such as validation and justification) compared to short-term projects (≤4 weeks) that were more focused on formulation and application. Second, the quality and intensity of teacher support and scaffolding. Studies that explicitly documented structured and responsive scaffolding strategies—such as just-in-time teaching and formative feedback—reported higher competency achievement and motivation than studies where the teacher's role was more laissezfaire or not detailed (Julanda et al., 2023; Kusmaryono & Wijayanti, 2020; Retnodari et al., 2020). Thus, the effectiveness of PjBL is not automatic but highly dependent on an instructional design that explicitly supports model-based thinking processes.

3.3. Challenges and Supporting Factors for Implementation

The implementation of PjBL for mathematical modeling in elementary schools faces a number of consistent challenges documented in the included studies, which can be categorized into pedagogical, cognitive, and institutional dimensions. Pedagogical challenges emerged as the most frequently cited category, encompassing difficulties in conducting ongoing and authentic process assessments, as well as inadequate teacher preparation and Pedagogical Content Knowledge (PCK) to facilitate open-ended and unstructured mathematical discussions that arise during the modeling process (Riani, 2023). Critically, this pedagogical challenge reflects a fundamental tension between traditional teacher-centered instructional paradigms and the constructivist demands of PjBL; teachers accustomed to delivering procedural knowledge often struggle to shift toward a facilitative role that requires responding to emergent student inquiries without predetermined answers to them. Cognitive challenges relate to the significant cognitive load perceived by students when managing project complexity, integrating knowledge from multiple domains (mathematics, science, literacy), and transitioning between concrete and abstract thinking. This is particularly pronounced given that elementary students are still operating within Piaget's concrete operational stage (Wibowo, 2024). This challenge is amplified by the dual demand of simultaneously learning mathematical content and mastering the metacognitive processes of modeling, suggesting that without adequate scaffolding, the cognitive burden may exceed students' developmental capacities. Institutional challenges include time management, where teachers reported difficulties in aligning long-term projects, often spanning 5–14 weeks, with rigid curriculum structures, fixed school schedules, and high-stakes, standardized testing pressures (Siregar, 2025). These institutional constraints reveal a systemic misalignment: the temporal flexibility required for authentic PjBL conflicts with the fragmented time allocations typical in elementary school settings, where mathematics instruction is often confined to 45–60 minute daily periods. Collectively, these constraints indicate that adopting PjBL is not merely a change in activity but a profound transformation of pedagogical practice that requires alignment across the individual, instructional, and systemic levels.

However, the analysis identified critical supporting factors that enabled successful implementation, which can likewise be categorized into teacher-related, student-related, and structural dimensions. Teacher-related supports center on the existence of targeted professional development focused on understanding the mathematical modeling cycle and PjBL facilitation strategies, which was reported to enhance teachers' confidence, pedagogical skills, and willingness to embrace uncertainty in the classroom. Critically, the most effective professional development was characterized by sustained engagement (not one-time workshops) and opportunities for collaborative reflection among teachers, suggesting that building teacher capacity requires ongoing practice-embedded learning rather than isolated training sessions. Student-related supports include effective collaboration among students, where peer discussion and peer assessment serve as internal support systems that help distribute cognitive load, provide multiple perspectives for problem-solving, and enrich the modeling process through collective sense-making. This finding underscores the social constructivist principle that knowledge construction in PjBL is inherently dialogic, with peer interactions compensating for individual cognitive limitations. Structural supports encompass two key elements: support from simple digital technologies, such as spreadsheet applications, graphic software, or simulators, which proved helpful in data visualization and model testing, making the abstraction process more accessible to young learners; and, most importantly, a strong connection between the project topic and students' life context and interests, which served as a powerful driver of intrinsic motivation capable of overcoming challenges related to engagement and persistence (Eriza & Hadi, 2023; Yunita et al., 2021). The critical role of contextual relevance suggests that authenticity cannot be superficial; projects must resonate with students' lived experiences to generate the sustained investment necessary to navigate the complexities of mathematical modeling. This synthesis affirms that a successful transition to PjBL depends on a supportive learning ecosystem involving institutional support for teachers, a collaborative classroom culture, appropriate utilization of tools, and, fundamentally, the strategic alignment of project design with students' cognitive capacities and developmental readiness.

3.4. Integrative Discussion

The evidence synthesis in this review strongly supports the theoretical proposition that PjBL provides an effective and contextual pedagogical framework for developing mathematical modeling competency in elementary schools. This suitability stems from the structural alignment between the iterative phases of PjBL and the mathematical modeling cycle. The extended investigation process of a project allows students to experience modeling not as a linear procedure but as a cyclical process of revision and refinement—a key aspect of authentic modeling that is often overlooked in direct instruction (Rehman et al., 2025; Wibowo, 2024; Yunita et al., 2021). The finding that the most significant improvement was seen in problem formulation and validation skills, not merely computation, underscores PjBL's strength in developing modeling as a practice, where mathematics serves as a tool for understanding the world, not merely as an end in itself.

These findings enrich and strengthen the theoretical framework of social constructivism in mathematics education by providing converging empirical evidence for it (Pranyata, 2023). Knowledge construction through authentic collaborative projects not only enhances conceptual understanding but also builds the habits of mind of a mathematical modeler, such as making assumptions, representing, and critiquing. This review also clarifies the limits of the effectiveness of this approach, emphasizing that constructivist theory in the context of PjBL requires the key element of planned and responsive instructional scaffolding (Arafah et al., 2023; Padmakrisya, 2024). Therefore, the underlying theory needs to integrate principles from cognitive load theory and sociocultural theory to explain why timely teacher support and structured collaboration are prerequisites for the successful construction of complex knowledge.

This review yields several actionable recommendations for practitioners. First, the selection or design of project themes must prioritize authenticity and local relevance to maximize student engagement in the project. Second, teachers should proactively design and implement differentiated scaffolding, such as templates and mini-lessons, particularly during the critical phase of translating contextual problems into mathematical representations. Third, the assessment system must shift from focusing on final answers to process-oriented assessment using rubrics that capture each stage of the modeling cycle. Fourth, schools should allocate sufficient time within their schedules and invest in ongoing professional development focused on mathematical modeling and PjBL facilitation strategies.

4. CONCLUSION

Based on the systematic synthesis of 17 empirical studies, it can be concluded that PjBL is an effective and applicable pedagogical approach for developing mathematical modeling competency and positive attitudes towards mathematics in elementary schools, with the caveat that its success is highly dependent on authentic project design, the provision of responsive and structured instructional scaffolding by teachers, and the implementation of authentic process assessment.

Three key implications emerge from this study for educational practice. First, teachers should prioritize project themes that are locally relevant and authentically connected to students' daily lives, as contextual relevance emerged as the strongest driver of intrinsic motivation and sustained engagement. Second, instructional design must embed structured scaffolding, including guided worksheets, just-in-time mini-lessons, and ongoing formative feedback, to support students' cognitive transition from concrete to abstract mathematical thinking, particularly during the problem formulation and model validation phases. Third, assessment systems should shift from product-focused grading to process-oriented evaluation using rubrics that capture each stage of the modeling cycle, enabling teachers to monitor and support student progress throughout the project duration.

Future research should pursue the following three prioritized directions. First, longitudinal studies are needed to investigate the sustainability of modeling competencies and affective gains beyond the immediate project timeframe, as the current evidence is limited to short-term outcomes. Second, large-scale experimental designs with rigorous controls and consistent effect size reporting are essential to strengthen causal evidence and enable meta-analytic synthesis to address the current predominance of small-scale studies. Third, development research should focus on designing, implementing, and evaluating sustainable professional development models that equip elementary teachers with the pedagogical content knowledge necessary to integrate PjBL and mathematical modeling effectively, with particular attention to diverse cultural and educational contexts, such as Indonesia, to examine the cross-cultural applicability of these findings.

Ethical Approval

Not Applicable

Informed Consent Statement

Not Applicable

Contributions of Authors

Not Applicable

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