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MAPPING THE CONTRIBUTION OF PROJECT-BASED LEARNING MODEL INTEGRATED WITH STEM ON MATHEMATICAL LITERACY: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Mathematical literacy requires students to formulate, employ, and interpret mathematics in real-world contexts. This Systematic Literature Review (SLR) examines how Project-Based Learning integrated with STEM (PjBL-STEM) has been studied in relation to mathematical literacy and related mathematical competencies. The review was guided by the PRISMA 2020 framework and covered identification, screening, eligibility assessment, evidence coding, and synthesis. The original search record reported 85 records, 52 records remaining after initial screening and duplicate/irrelevant-record removal, and 25 sources selected for analysis. Searches were reported in Scopus and Google Scholar; however, the retained search record does not identify additional sources or preserve the database-specific search logs. Studies were considered according to publication period (2016–2025), relevance to PjBL/STEM and mathematical outcomes, source verifiability, and their classification as direct, adjacent, or contextual evidence. The reviewed sources were examined through descriptive and thematic synthesis, with reported findings mapped to the OECD processes of formulate, employ, and interpret. The revised synthesis identifies research trends, maps reported evidence to the OECD processes of formulate, employ, and interpret, and synthesizes supporting and hindering implementation factors and evidence-based research gaps. The literature provides recurring evidence for contextual learning, mathematical modelling, problem solving, collaboration, and higher-order thinking, but direct evidence specifically testing STEM-PjBL effects on mathematical literacy remains limited. The three OECD dimensions are not equally or explicitly assessed across studies. Common implementation barriers include instructional time, teacher readiness, and learning resources. Accordingly, STEM-PjBL is treated as a promising instructional framework rather than as a demonstrated superior intervention.

Keywords: Mathematical Literacy, Project-Based Learning, STEM-Integrated Learning, Systematic Literature Review.

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PRELIMINARY

The 21st century has shifted mathematics education toward learning environments in which students are expected to reason, solve problems, communicate, collaborate, and apply mathematical ideas in meaningful contexts. Mathematical literacy is particularly

important because it concerns the capacity to formulate, employ, and interpret mathematics in a variety of real-world situations (OECD, 2023). In Indonesia, PISA 2022 results show that mathematics performance remained below the OECD average, reinforcing the need for learning experiences that connect mathematical concepts with contextual problems (OECD, 2023).

Project-Based Learning (PjBL) provides a learning structure in which students investigate authentic questions, plan and produce a project, collaborate, solve problems, and communicate results. These characteristics can support mathematical literacy when the project requires students to identify the mathematical structure of a situation, select appropriate representations or procedures, and interpret the resulting solution in context. STEM education contributes a complementary interdisciplinary context in which mathematics can be connected with science, technology, and engineering through modelling, data use, design constraints, testing, and revision. Thus, PjBL contributes the inquiry and project structure, whereas STEM contributes interdisciplinary problem contexts and design or modelling practices. Their integration may create more opportunities for students to move between contextual situations and mathematical representations; however, the integration itself does not constitute evidence of greater effectiveness than PjBL or STEM implemented separately.

Previous reviews and empirical studies have often emphasized general achievement, critical thinking, creativity, problem solving, or STEM implementation rather than mathematical literacy as a specifically measured outcome. The reviewed literature also differs in educational level, subject context, intervention design, and outcome measures. Consequently, evidence about the three OECD dimensions, formulate, employ, and interpret cannot be assumed to be equivalent across all studies. In this review, studies that examine PjBL or STEM separately are therefore treated as adjacent or contextual evidence and are not presented as direct evidence for the combined STEM-PjBL intervention.

The present review addresses this gap by distinguishing direct evidence from adjacent and contextual evidence and by synthesizing findings according to four research questions (RQs): (1) What are the trends in STEM-PjBL research related to mathematical literacy during 2016–2025? (2) How does the reviewed evidence relate to the OECD dimensions of formulate, employ, and interpret? (3) What factors support or hinder STEM-PjBL implementation? and (4) What evidence-based research gaps remain? To clarify the

novelty, the review also compares its scope with prior reviews on STEM-PjBL, integrated STEM, and PjBL.

Table 1. Comparison of Prior Reviews and the Present Review

Review/source	Primary focus documented in the retained evidence	Relation to the present review
(Thibaut et al., 2018)	Integrated STEM education; systematic review of instructional practices in secondary education	Provides integrated-STEM context; does not specifically center mathematical literacy in STEM-PjBL.
(Setyawati et al., 2022)	STEM-PjBL and mathematical critical thinking; systematic literature review	Addresses STEM-PjBL and critical thinking; the present review centers mathematical literacy and OECD processes.
(Goos et al., 2023)	Interdisciplinary STEM and mathematics; literature review	Provides mathematics/STEM context; the present review focuses on STEM-PjBL and mathematical-literacy evidence mapping.
(Lee & Lee, 2025)	PjBL as a catalyst for integrated STEM education; literature review	Examines PjBL/STEM integration broadly; the present review adds an explicit mathematical-literacy and OECD-dimension coding frame.

METHODS

Research Approach and Design

This review follows the PRISMA 2020 reporting framework for systematic reviews. The retained research record provides the original search counts, but it does not preserve the exact database-specific search logs or exact search date. Those missing details are explicitly identified rather than invented. The review process is reported in terms of information sources, search strategy, eligibility criteria, study selection, evidence coding, quality-appraisal considerations, and thematic synthesis. The synthesis was descriptive and thematic: sources were coded by year, instructional focus, research design/type, mathematical outcome, evidence role, OECD process, implementation factors, and reported limitations.

Information Sources and Search Strategy

The original manuscript reported searches in Scopus and Google Scholar. Because the retained manuscript does not identify the additional sources individually, this revision does not invent a database list. The recorded core concepts were “Project-Based Learning,” “STEM,” and “mathematical literacy.” The standardized Boolean formulation below clarifies the relationship among these concepts and the keywords; it should not be interpreted as a recoverable database-specific search log.

For consistency with the title and keywords, the search concepts can be represented by the following standardized Boolean formulation: (“mathematical literacy” OR “math literacy” OR numeracy OR “mathematical modelling”) AND (“project-based learning” OR

PjBL OR "project based learning") AND (STEM OR "integrated STEM" OR "STEM education" OR "STEM-integrated learning"). The phrase "systematic literature review" is included as a standardized keyword describing the review type; it should be reported as a database search term only if it was actually used in the original search. Database-specific syntax, filters, and the exact last-search date should be verified against the authors' original search history before submission. The eligibility period was 2016–2025; this period was selected to capture the recent development of STEM-integrated PjBL research while retaining older foundational works only as theoretical background.

Search-date verification note: the exact date of the original database searches was not retained in the manuscript files supplied for revision. The authors should insert the verified search date before final submission rather than using an estimated date.

Eligibility Criteria

The eligibility criteria were established to ensure that the selected studies were relevant to the research objectives and provided an appropriate basis for synthesizing evidence on the integration of Project-Based Learning (PjBL) and Science, Technology, Engineering, and Mathematics (STEM) in mathematics education, particularly in relation to students' mathematical literacy. The selection process considered several criteria, including publication year, direct evidence focus, adjacent or contextual evidence, outcome relevance, and publication source. These criteria were applied systematically to distinguish studies that provided direct empirical evidence from those that served primarily as theoretical or contextual support.

Furthermore, outcome relevance was assessed by considering studies addressing mathematical literacy, mathematical modelling, mathematical problem-solving, mathematical reasoning, and contextual mathematical application. The role of each study was explicitly classified to maintain transparency in the evidence synthesis and avoid overgeneralizing findings beyond their actual research scope. Regarding publication sources, eligible records included articles published in indexed or reputable journals, conference proceedings, and authoritative reports with sufficient bibliographic information. Duplicate records and publications that could not be verified were excluded. The detailed inclusion and exclusion criteria applied during the study selection process are presented in Table 2.

Table 2. Eligibility Criteria for Study Selection

Criterion	Inclusion	Exclusion
Publication year	2016–2025 for the evidence set; pre-2016 sources may be retained only as theoretical background.	Before 2016 or after 2025 when used as evidence in the review synthesis.
Direct evidence focus	Studies explicitly examining STEM-integrated PjBL and reporting mathematical literacy or a clearly defined mathematical competency outcome.	Studies examining unrelated interventions or outcomes.
Adjacent/contextual evidence	Studies of PjBL or STEM separately, STEM-PjBL in another subject, or theoretical/framework sources may be retained only to explain mechanisms, context, or implementation; they are not treated as direct STEM-PjBL evidence.	Using adjacent/contextual studies as if they directly tested STEM-PjBL effects on mathematical literacy.
Outcome relevance	Mathematical literacy, mathematical modelling, mathematical problem solving, reasoning, or contextual mathematical application, with the evidence role explicitly coded.	Studies with no relevant mathematical or learning outcome.
Publication source	Indexed/reputable journal articles, conference proceedings, and authoritative reports with sufficient bibliographic information.	Duplicate or unverifiable records.

Study Selection and PRISMA Flow

The original manuscript reported 85 initial records. After duplicate removal and title/abstract screening for relevance, 52 records remained. Twenty-five sources were then retained in the original final synthesis. During revision, the evidence role of each source was reconsidered: direct STEM-PjBL evidence was separated from adjacent empirical evidence and contextual/framework evidence. Three pre-2016 foundational sources (Krajcik & Blumenfeld, 2006; Bybee, 2013) are not counted in the 2016–2025 evidence set. Firdaus et al. (2021) is identified as Problem-Based Learning rather than Project-Based Learning and is therefore not treated as direct STEM-PjBL evidence. The PRISMA diagram retains the original counts because the original search log does not preserve the

exact duplicate and full-text exclusion counts; these should be verified against the search history before final submission.

During title-and-abstract screening, records were assessed against the predefined eligibility criteria. Full-text reports were then examined to determine whether they provided relevant evidence on PjBL, STEM, mathematical learning outcomes, or the implementation context. Reports were excluded when they did not meet the publication-period criteria, did not address a relevant instructional approach or mathematical outcome, or lacked sufficient bibliographic/full-text information for verification. The number of reports excluded under each reason is presented in the PRISMA flow diagram.

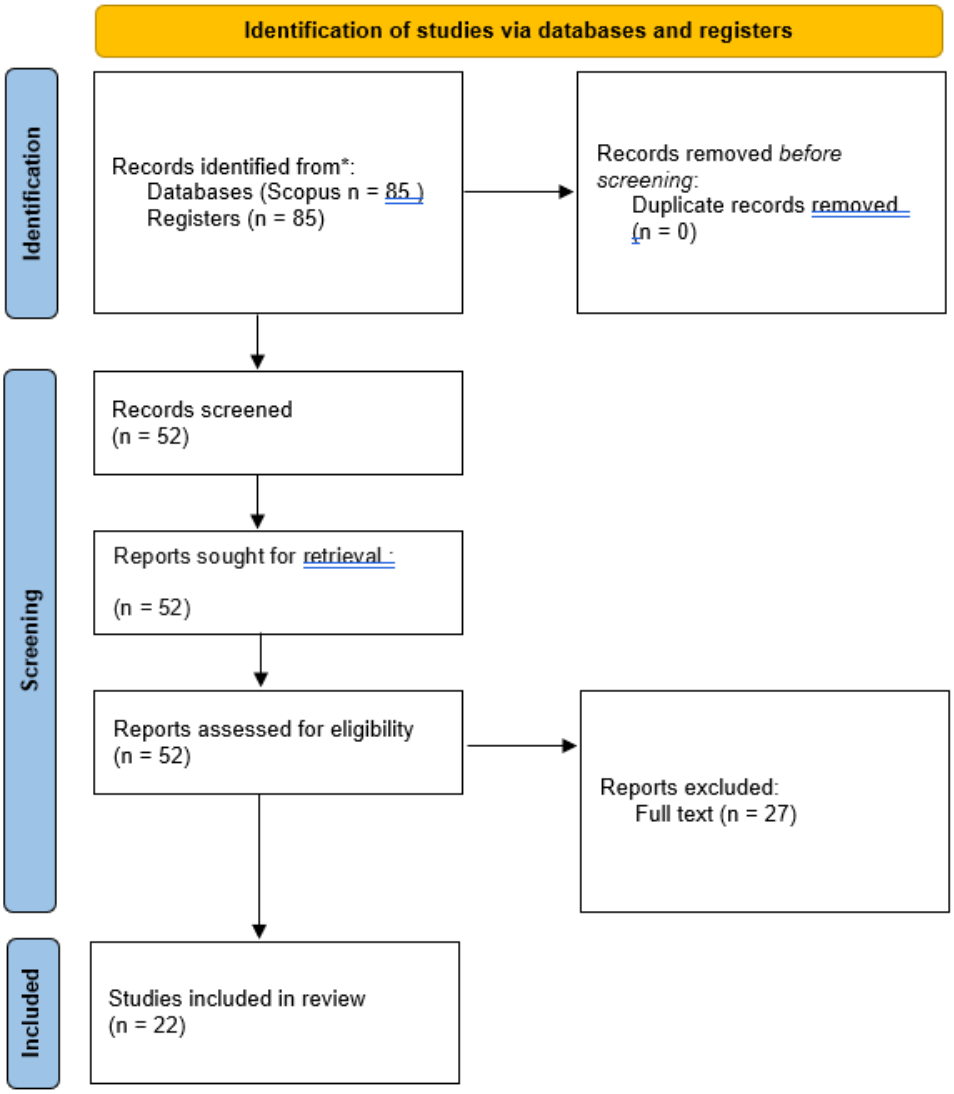


Figure 1. PRISMA-Oriented Flow of Study Identification and Selection

Coding and Synthesis

Each included source was coded by publication year, instructional focus, research design/type, mathematical outcome, relation to STEM-PjBL, evidence role, OECD literacy dimension, implementation factors, and reported research limitations. Three evidence categories were used: (1) direct evidence, studies explicitly examining STEM-PjBL with a mathematical-literacy or closely defined mathematical outcome; (2) adjacent empirical evidence, studies examining PjBL or STEM separately, or STEM-PjBL in another subject, that inform mechanisms or implementation; and (3) conceptual/contextual evidence, frameworks, reports, and theoretical/review sources used to define constructs or interpret findings.

For RQ2, an OECD dimension was coded as "explicit" only when the source directly measured or clearly reported that process; otherwise it was coded as "not explicit" and was not treated as direct evidence. Retrospective mapping is reported separately from explicit measurement.

Quality Assessment

A quality-appraisal framework was added to distinguish methodological strength from relevance. The appraisal domains were study-design clarity, description of participants/context, clarity of the intervention or learning approach, alignment between the outcome measure and the review question, and acknowledgement of limitations.

The original manuscript did not retain completed study-level appraisal forms or scores; therefore, no numerical quality score is fabricated in this revision. Instead, quality is used as a synthesis qualifier: direct studies with clearly described outcomes receive greater evidential weight than adjacent or conceptual sources. This limitation is explicitly retained as a methodological gap and should be addressed by completing a study-level appraisal table from the original full texts before final submission if required by the journal.

Each included empirical study was appraised against five domains: (1) clarity of the study design; (2) adequacy of the description of participants and context; (3) clarity of the instructional intervention or learning approach; (4) alignment between the outcome measure and the review question; and (5) acknowledgement of study limitations. Each domain was judged as "Yes", "Partly", "No", or "Not applicable". The appraisal was used to qualify the interpretation of the evidence and was not treated as a measure of intervention effectiveness.

RESULT AND DISCUSSION

RQ1. Research trends during 2016–2025

After separating three pre-2016 foundational sources from the evidence set, 22 sources dated 2016–2025 remain in the revised evidence mapping. The set is heterogeneous and includes direct STEM-PjBL studies, adjacent PjBL or STEM studies, reviews, conceptual papers, and studies from science or physics contexts. The publication distribution is concentrated in 2021–2025.

Because the retained record does not consistently report educational level, geographical context, or mathematical topic for every source, those characteristics are not inferred. Instead, the synthesis reports only characteristics directly documented in the retained evidence and identifies the missing study-level descriptors as a reporting gap.

Table 3. Characteristics of the Included Studies and Their Evidence Roles

Sources	Type	Main focus	Evidence role
(Boaler, 2016)	Theoretical	Mathematical learning/mindset	Contextual
(Lou et al., 2017)	Experimental	STEM-PjBL; motivation/achievement	Adjacent
(English, 2023) ; (Thibaut et al., 2018)	Theoretical/review	STEM; mathematical reasoning/problem solving	Adjacent
OECD	Framework/report	Mathematical literacy framework	Contextual
(Wahono et al., 2020)	Experimental/mixed	PjBL creativity; STEM mathematics	Adjacent
(Firdaus et al., 2021) ; (Nugroho et al., 2021);	Experimental/quasi-experimental	PBL mathematics; STEM literacy; STEM-PjBL skills	Adjacent
(Setyawati et al., 2022).	Review/survey/experimental	STEM-PjBL; implementation; science; modelling	Mostly adjacent
(Goos et al., 2023) ; (OECD 2023)	Review/report	Interdisciplinary STEM; PISA 2022	Contextual
	Quasi-experimental	PjBL problem solving	Adjacent
(Himmi et al., 2025); (Lee & Lee, 2025)	Review/experimental/development/conceptual	PjBL, STEM, mathematical literacy, implementation	Mixed

RQ2. Contribution to Formulate, Employ, and Interpret

The revised synthesis does not treat the three OECD dimensions as equally demonstrated. Formulate refers to identifying the mathematical structure of a contextual situation and translating it into mathematical representations; employ refers to selecting

and using mathematical concepts, procedures, models, or reasoning; and interpret refers to explaining, evaluating, or reconnecting mathematical results to the original context.

The article-level mapping below distinguishes explicit measurement from retrospective interpretation. Most reviewed sources provide activity or outcome descriptions that are compatible with one or more OECD processes, but only a limited subset explicitly assesses the OECD dimensions as mathematical-literacy indicators.

Table 4. Article-Level Mapping of Reviewed Evidence to OECD Processes

Source (year)	Evidence role	Formulate	Employ	Interpret	Coding basis/limitation
Boaler (2016)	Contextual	Not explicit	Not explicit	Not explicit	Mathematical learning/mindset framework; no direct OECD dimension measure.
Lou et al. (2017)	Adjacent	Not explicit	Not explicit	Not explicit	STEM-PjBL study focused on creativity; not mathematical literacy.
English (2018)	Adjacent	Not explicit	Compatible	Not explicit	STEM and mathematical thinking; dimension not explicitly measured.
Thibaut et al. (2018)	Adjacent	Not explicit	Compatible	Not explicit	Integrated STEM review; instructional practices rather than OECD literacy measurement.
OECD (2019)	Contextual	Explicit framework	Explicit framework	Explicit framework	Defines the OECD literacy processes; contextual framework, not an intervention study.
Wahono et al. (2020)	Adjacent	Not explicit	Compatible	Not explicit	STEM integration in secondary mathematics; outcome focus includes problem solving/engagement.
Firdaus et al. (2021)	Excluded from direct STEM-PjBL evidence	Not explicit	Compatible	Not explicit	Problem-Based Learning (PBL), not Project-Based Learning (PjBL).
Nugroho et al. (2021)	Adjacent	Not explicit	Compatible	Not explicit	STEM learning and literacy; combined STEM-PjBL mathematical-literacy

Source (year)	Evidence role	Formulate	Employ	Interpret	Coding basis/limitation
					measurement not established in retained summary.
Setyawati et al. (2022)	Adjacent	Not explicit	Compatible	Not explicit	STEM-PjBL and critical thinking; OECD dimensions not explicitly assessed.
Goos et al. (2023)	Adjacent/contextual	Not explicit	Compatible	Not explicit	Interdisciplinary STEM and mathematics; review evidence.
OECD (2023)	Contextual	Explicit framework	Explicit framework	Explicit framework	PISA 2022 framework/results; not a STEM-PjBL intervention study.
Himmi et al. (2025)	Adjacent	Not explicit	Not explicit	Not explicit	PjBL in mathematics; higher-order thinking focus.
Lutfiyana et al. (2025)	Direct/closely related	Compatible	Compatible	Compatible, not separately reported	Reports STEM with PjBL-related learning and mathematical literacy; exact OECD dimension measurement requires full-text verification.
Lee & Lee (2025)	Adjacent	Not explicit	Compatible	Not explicit	PjBL as catalyst for integrated STEM; broad integration focus.

The reviewed studies were further analyzed based on the three OECD mathematical literacy dimensions: formulate, employ, and interpret. This analysis shows how these dimensions are represented in the existing literature and highlights the strengths and limitations of the available evidence. The results are summarized in Table 5.

Table 5. Evidence of Mathematical Literacy Dimensions in the Reviewed Literature

OECD dimension	Evidence pattern in reviewed literature	Strength/limitation
Formulate	Contextual problem identification; translating situations into mathematical representations; modelling	Evidence is mainly indirect/adjacent; explicit OECD-aligned measurement is limited
Employ	Applying mathematical concepts, procedures, modelling and reasoning	More consistently represented in

OECD dimension	Evidence pattern in reviewed literature	Strength/limitation
	during projects	modelling/problem-solving studies
Interpret	Explaining or evaluating results and reconnecting mathematical solutions to context	Least explicitly measured; often inferred from project/reporting activities

Coding Frequencies and the Four Original Percentages

The original manuscript reported 80%, 70%, 65%, and 40%. The reviewers correctly noted that these percentages were not traceable to a retained coding sheet. Because the original coding data are not contained in the manuscript, the percentages are removed rather than recalculated from assumptions. The revised synthesis therefore uses qualitative evidence categories and an article-level coding table. No pooled percentage is reported where the underlying study-level counts cannot be reconstructed.

Table 6. Summary of Evidence Coding Categories in the Reviewed Literature

Coding Category	Frequency Status	Interpretation
Direct STEM-PjBL + mathematical literacy	Very limited	The selected literature does not provide enough clearly documented direct comparative evidence to support a pooled percentage.
PjBL-related higher-order thinking/problem solving	Present in multiple sources	Includes studies focused on PjBL or related approaches; should not be equated with direct mathematical-literacy evidence.
STEM-related modelling/conceptual understanding	Present in multiple sources	Useful as mechanism/adjacent evidence, but not evidence of the combined intervention by itself.
Implementation barriers	Repeated across sources	Time, teacher readiness, and resources recur in the reviewed literature.

RQ3. Supporting and Hindering Factors

Across the reviewed literature, several mechanisms repeatedly support STEM-PjBL implementation: authentic or contextual problems, collaboration, interdisciplinary tasks, mathematical modelling, student inquiry, and opportunities to communicate or reflect on solutions. These mechanisms provide plausible pathways through which mathematical

literacy may be developed. Practical barriers include limited instructional time, teacher readiness, and learning resources or facilities. Because several studies are small, scale or focus on outcomes other than mathematical literacy, these factors are interpreted as recurring implementation themes rather than quantified causal determinants.

This pattern is consistent with the broader literature on project-based learning. Kokotsaki et al. (2016) describe PjBL as a student-centred approach involving constructive investigation, collaboration, communication, and reflection, while also emphasizing the importance of teacher scaffolding and the alignment of assessment with learning goals. These conditions help explain why collaboration and inquiry recur as supportive features in the reviewed studies; however, they should be understood as implementation conditions rather than proof that PjBL-STEM automatically improves mathematical literacy.

The interdisciplinary dimension also requires deliberate instructional design. Kelley and Knowles (2016) argue that integrated STEM connects two or more STEM domains through STEM practices in an authentic context. English (2016) further cautions that mathematics needs to remain visible and substantive within STEM integration rather than being overshadowed by science or engineering activities. Therefore, a project should require students to use mathematical ideas, representations, quantitative reasoning, or modelling to make and justify decisions; simply producing a physical product is not sufficient evidence of mathematical learning.

Teacher readiness and access to suitable learning resources are also relevant to implementation quality. Stohlmann et al. (2012) identify teachers' knowledge, experiences, efficacy, and instructional materials as important considerations for teaching integrated STEM. Similarly, Roehrig et al. (2012) show that the presence of engineering standards alone does not guarantee meaningful STEM integration; the connections among disciplines need to be intentionally enacted. These studies support interpreting teacher preparation and resource availability as enabling conditions, while the present review does not quantify their causal effects.

RQ4. Research Gaps

A further issue concerns the operational definition and quality of integrated STEM. Roehrig et al. (2021) propose that integrated STEM should be examined through identifiable features such as authentic problem contexts, integration of disciplinary content, STEM practices, and engineering design. Their framework highlights why studies using the label "STEM" may not be directly comparable when the nature and depth of integration are not clearly described. For future mathematical-literacy research, authors should

therefore report not only the project theme but also which mathematical concepts are taught, how mathematics is connected to the other STEM domains, and how students' mathematical reasoning is assessed.

Direct evidence on STEM-PjBL and mathematical literacy is limited compared with evidence on general achievement, creativity, critical thinking, problem solving, or STEM implementation. This limits the strength of any general effectiveness claim. The three OECD dimensions are rarely measured separately with validated or explicitly aligned indicators. This creates an evidence gap between descriptions of project activities and direct measurement of mathematical literacy.

Many studies use short interventions and small samples, limiting conclusions about durability, transfer, and applicability across educational settings. Studies differ substantially in educational level, mathematical topic, STEM configuration, project duration, and outcome measures. The literature therefore does not yet provide a uniform evidence base across domains or contexts. Direct comparison between STEM-PjBL and PjBL or STEM alone is insufficient in the reviewed set; therefore, superiority claims are not warranted.

This interpretation is also aligned with the OECD (2023) assessment framework, which defines mathematical literacy through the processes of formulating situations mathematically, employing mathematical concepts and procedures, and interpreting or evaluating mathematical outcomes in context. Consequently, future evaluations of STEM-PjBL should make these processes explicit in learning tasks and assessment instruments. The evidence reviewed here supports the instructional plausibility of this alignment, but it does not establish a general causal or comparative advantage for STEM-PjBL over PjBL or STEM approaches implemented separately.

Future studies should use clearer comparison conditions, larger and more diverse samples, longitudinal designs, explicit mathematical-literacy measurement, study-level quality appraisal, and transparent coding of formulate, employ, and interpret. These are evidence-based gaps derived from the characteristics of the reviewed studies rather than general recommendations alone.

Integrated Synthesis

Taken together, the reviewed evidence suggests that STEM-PjBL can create learning conditions compatible with mathematical-literacy development, especially when projects require students to understand authentic situations, construct or use mathematical models, reason with quantitative information, and communicate conclusions. However,

compatibility of a learning process with mathematical literacy is not equivalent to proof of effectiveness on the OECD construct.

The strongest recurring evidence concerns related competencies such as modelling, problem solving, collaboration, and higher-order thinking, while direct evidence using explicit mathematical-literacy measures remains comparatively sparse. The principal contribution of this review is therefore a structured evidence map linking reported STEM-PjBL activities to mathematical-literacy dimensions while clearly distinguishing direct, adjacent, and contextual evidence.

CONCLUSION

For mathematics educators, the reviewed evidence suggests that STEM-PjBL is most plausibly connected to mathematical literacy when project tasks require students to formulate a contextual problem, employ mathematical representations or models, and interpret or evaluate results. Implementation should therefore include sufficient time, teacher preparation, appropriate resources, and opportunities for student discussion and reflection. For researchers, the review highlights the need to report explicit mathematical-literacy indicators, study-level quality appraisal, intervention fidelity, and comparison conditions so that future reviews can distinguish demonstrated effects from theoretically compatible learning processes. RQ1: Research trends. The revised evidence set contains 22 sources published during 2016–2025 after three pre-2016 foundational references were removed from the evidence table. Research activity is concentrated in 2021–2025, but the literature is heterogeneous and includes direct, adjacent, and contextual evidence. RQ2: Formulate, employ, and interpret. The literature describes activities compatible with all three OECD processes, particularly contextual problem identification, mathematical modelling, application of mathematical concepts, and explanation of results. However, the three dimensions are not equally or explicitly measured across studies. The mapping therefore supports a cautious association between STEM-PjBL activities and mathematical-literacy processes rather than a uniform demonstrated effect. RQ3 and RQ4: Implementation factors and research gaps. Recurring supporting conditions include authentic contexts, collaboration, interdisciplinary tasks, modelling, inquiry, and communication or reflection. Recurring barriers include instructional time, teacher readiness, and learning resources. Major evidence-based gaps include limited direct mathematical-literacy measurement, limited study-level quality appraisal, short interventions, small or heterogeneous samples, variation in mathematical topics and

educational contexts, and insufficient direct comparison with PjBL or STEM alone. Accordingly, STEM-PjBL should be understood as a promising framework, while stronger causal or comparative conclusions require more rigorous evidence.

DECLARATIONS

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