

# Instructional Models For Enhancing Students' Mathematical Literacy in Secondary Education: A Systematic Literature Review

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## ABSTRACT

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Various instructional models have been developed to improve students' mathematical literacy; however, empirical evidence regarding their characteristics and effectiveness remains fragmented across the literature. This study aimed to identify, classify, and synthesize the instructional models used to enhance mathematical literacy among secondary school students. A systematic literature review (SLR) was conducted following the PRISMA 2020 guidelines. The literature search was performed in the Scopus and Education Resources Information Center (ERIC) databases and included peer-reviewed journal articles published between 2017 and 2026. Of the 95 records initially identified, 24 studies met the inclusion criteria and were included in the final synthesis. The findings indicate that the use of contextual, authentic, and culturally relevant problems is the most prominent characteristic of mathematics instruction for developing mathematical literacy. In addition, Problem-Based Learning (PBL), Project-Based Learning (PjBL), STEM/STEAM-based approaches, digital technology integration, and Realistic Mathematics Education (RME) were the instructional models most frequently implemented. Most studies reported improvements in students' mathematical literacy following the implementation of these models, particularly when instruction incorporated problem-solving, mathematical modeling, collaboration, reflection, and meaningful uses of technology. Nevertheless, the available evidence is largely concentrated in the Indonesian context and exhibits considerable methodological diversity. Future research should therefore examine the effectiveness of instructional models across more diverse educational contexts and investigate their long-term impact on the development of students' mathematical literacy.

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## 1. INTRODUCTION

Mathematical literacy is an essential competency that enables students to address problems that do not always appear in the form of routine exercises. The Organisation for Economic Co-operation and Development (OECD) defines mathematical literacy as an individual's capacity to reason mathematically and to formulate, apply, and interpret mathematics in a variety of real-world contexts (OECD, 2023a). This competency includes the ability to use mathematical concepts, procedures, facts, and tools to explain phenomena and support informed decision-making. Its importance becomes increasingly evident at the secondary education level, where students encounter social, economic, scientific, and technological issues that require evidence-based reasoning. However, the PISA 2022 results showed that the average mathematics score of Indonesian 15-year-old students was 366, compared with the OECD average of 472 (OECD, 2023b). These findings highlight the need for mathematics instruction that extends beyond procedural proficiency to foster students' ability to use mathematics meaningfully in everyday life.

Within secondary education, mathematical literacy should be viewed as more than computational proficiency. Students are expected not only to obtain correct answers but also to identify relevant information, transform real-world situations into mathematical representations, evaluate the reasonableness of their results, and justify the strategies they use. These competencies become increasingly important as mathematical concepts become more abstract while their applications become more closely connected to everyday decision-making, including interpreting data, assessing risk, and solving contextualized problems. Consequently, instructional approaches that focus primarily on procedural practice may be insufficient to promote knowledge transfer. Schools therefore require instructional models that engage students with authentic problems, encourage discussion and reflection, and connect mathematical concepts with real-life experiences.

Strengthening mathematical literacy requires instructional designs that provide opportunities for students to understand situations, construct mathematical models, select appropriate strategies, communicate their reasoning, and evaluate their solutions. Sumirattana et al. (2017) demonstrated that integrating Realistic Mathematics Education (RME) with the DAPIC problem-solving process improved secondary students' mathematical literacy through the use of real-life problems, collaborative discussion, mathematical formalization, and knowledge application. In the Indonesian context, Putri et al. (2021) developed a healthy menu project that connected arithmetic operations with students' daily calorie requirements. Similarly, Rachmaningtyas et al. (2022) found that strengthening mathematical literacy among junior secondary school students was associated with sustained reading practices, the implementation of project-based learning and problem-based learning according to students' needs, and the use of higher-order thinking skills (HOTS)-oriented tasks.

Recent studies have also demonstrated an increasing diversification of instructional models. Komarudin et al. (2024) reported the potential of the Reading, Mind Mapping, and Sharing (RMS) model combined with brainstorming to enhance both mathematical literacy and digital literacy among secondary school students. Srikoon et al. (2024) developed the STEMEN model, which integrates STEM education with educational neuroscience to improve mathematical literacy and

problem-solving skills. Technological integration has also advanced through Virtual Realistic Mathematics Education, which combines virtual learning environments with the principles of RME (Çakıroğlu et al., 2024). In addition, Supianti et al. (2025) investigated STEAM-based Project-Based Learning to promote students' mathematical literacy and character development, while Cahyono et al. (2025) employed technology-assisted math trails to connect mathematics with students' surrounding environments. Furthermore, Boonsot and Chookhampaeng (2025) proposed a comprehensive instructional model consisting of theoretical foundations, instructional objectives, learning procedures, social systems, response principles, and support systems.

These findings suggest that improvements in mathematical literacy cannot be attributed to a single instructional model. Learning outcomes may vary depending on the characteristics of the instructional model, the nature of the contextual problems, the integration of technology, collaborative learning patterns, grade level, intervention duration, and the outcome indicators employed. Putri et al. (2024) conducted a meta-analysis of 17 studies in Indonesia and concluded that Realistic Mathematics Education has a positive effect on students' mathematical literacy. Although this study provides valuable evidence, it focuses exclusively on one instructional approach within a single national context. Existing research remains dispersed across experimental, developmental, and exploratory studies, each emphasizing different instructional models and educational outcomes. Consequently, there is still no comprehensive synthesis identifying which instructional models have been implemented in secondary education, how these models have been applied, and what empirical evidence supports their effectiveness.

Given this situation, a systematic literature review is needed to organize the available empirical evidence in a transparent and systematic manner. This review aims to identify, classify, and analyze the instructional models used to improve mathematical literacy among secondary school students. The analysis focuses on the types of instructional models, their pedagogical characteristics, implementation contexts, technology integration, research designs, mathematical literacy indicators, and reported learning outcomes. Specifically, this review addresses three questions: (1) What instructional models have been employed to improve mathematical literacy in secondary education? (2) What pedagogical characteristics are most commonly represented across these models? and (3) What patterns of learning outcomes have been reported? The findings are expected to provide a comprehensive overview of current research, identify well-established and underexplored areas, and offer a conceptual foundation for researchers and educators in designing mathematics instruction that meets the demands of twenty-first-century mathematical literacy.

## 2. METHOD

This study employed a **systematic literature review (SLR)** to identify, select, evaluate, and synthesize empirical studies on instructional models used to improve mathematical literacy among secondary school students. An SLR was chosen because it provides a structured, transparent, and reproducible approach to

literature searching and evidence synthesis, thereby minimizing reliance on narrative or arbitrary reference selection (Snyder, 2019; Xiao & Watson, 2019).

The review followed the main stages of a systematic literature review: (1) formulating the research questions; (2) establishing the eligibility criteria; (3) identifying information sources; (4) developing the search strategy; (5) removing duplicate records and screening studies; (6) assessing methodological quality; (7) extracting relevant data; and (8) synthesizing the findings. The study selection process was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Page et al., 2021a). In addition, the search strategy was documented following the PRISMA-S reporting guideline to ensure that the search terms, databases, search limits, and numbers of retrieved records could be systematically traced and replicated (Rethlefsen et al., 2021).

This review was conducted to address the following research questions:

1. What instructional models have been used to improve the mathematical literacy of secondary school students?
2. What pedagogical characteristics do these instructional models exhibit, including the use of contextual problems, collaborative learning activities, technology integration, and assessment approaches?
3. What are the characteristics of the available studies in terms of publication year, country, educational level, research design, participant characteristics, and implementation duration?
4. What patterns of findings have been reported regarding improvements in students' mathematical literacy?
5. What research gaps remain in the development of instructional models for mathematical literacy in secondary education?

### **Inclusion and Exclusion Criteria**

The inclusion and exclusion criteria were established before the screening process to reduce the risk of selection bias. These criteria were developed by considering the target population, primary concept, educational context, study design, publication type, language, and publication period.

<b>Aspect</b>	<b>Inclusion Criteria</b>	<b>Exclusion Criteria</b>
<b>Population</b>	Secondary school students or equivalent educational levels, including middle school, junior high school, secondary school, and senior high school	Primary school students, university students, teachers, or participants in professional training programs when data from secondary school students could not be separated

<b>Target Competency</b>	Mathematical literacy, mathematics literacy, numeracy literacy, or related competencies involving the application of mathematics in real-world contexts	Basic computational skills, general mathematics achievement, or numerical ability unrelated to mathematical literacy
<b>Intervention</b>	Instructional models, approaches, strategies, or instructional designs implemented to develop or improve mathematical literacy	Studies focusing solely on developing assessment instruments, measuring baseline ability, or analyzing students' difficulties without implementing instructional interventions
<b>Study Design</b>	Empirical quantitative, qualitative, mixed-methods, experimental, quasi-experimental, case study, and development studies that include implementation and evaluation	Conceptual papers, editorials, conference proceedings without adequate peer review, book reviews, undergraduate theses, master's theses, doctoral dissertations, and non-academic reports
<b>Publication Type</b>	Peer-reviewed journal articles	Duplicate publications, articles without full-text access, or studies with insufficient methodological information
<b>Language</b>	English or Indonesian	Publications in other languages without a full-text version available in English or Indonesian
<b>Publication Period</b>	January 2017 to June 3, 2026	Studies published before 2017

The publication period from 2017 to 2026 was selected to capture the development of instructional models over approximately the past decade. This period includes early studies on the integration of Realistic Mathematics Education (RME) and the DAPIC problem-solving process for secondary school students, while also encompassing more recent developments such as STEM, STEAM, project-based learning, collaborative learning, and the integration of digital technologies into mathematics instruction.

## Information Sources and Search Strategy

The literature search was conducted on June 3, 2026, using two electronic databases: Scopus and the Education Resources Information Center (ERIC). Scopus was selected to retrieve a broad range of multidisciplinary, internationally indexed publications, whereas ERIC was included to strengthen the coverage of studies in the field of education. All retrieved records were exported in RIS or NBIB format to facilitate metadata management and the removal of duplicate records.

The search strategy was developed by combining three groups of search terms: (1) terms related to mathematical literacy; (2) terms referring to instructional models or teaching strategies; and (3) terms describing secondary education. The Boolean operator AND was used to connect the three conceptual groups, whereas OR was employed to incorporate alternative or synonymous search terms within each group. The final search strategy for Scopus was formulated as follows:

```
TITLE-ABS-KEY(  
  ("mathematical literacy" OR "mathematics literacy"  
   OR "numeracy literacy" OR numeracy)  
  AND  
  ("instructional model*" OR "teaching model*" OR "learning model*"  
   OR "pedagogical model*" OR "instructional strateg*"  
   OR "teaching strateg*" OR "learning approach*"  
   OR intervention* OR "problem-based learning"  
   OR "project-based learning" OR "realistic mathematics education"  
   OR STEM OR STEAM OR "cooperative learning"  
   OR "collaborative learning" OR "blended learning")  
  AND  
  ("secondary education" OR "secondary school*"  
   OR "middle school*" OR "junior high school*"  
   OR "senior high school*" OR adolescent*  
   OR "grade 7" OR "grade 8" OR "grade 9"  
   OR "grade 10" OR "grade 11" OR "grade 12")  
)  
AND PUBYEAR > 2016  
AND PUBYEAR < 2027
```

The search strategy for **ERIC** was adapted to the search syntax and indexing structure of the database, as follows:

```
("mathematical literacy" OR "mathematics literacy"  
 OR "numeracy literacy" OR numeracy)  
AND  
("instructional model" OR "teaching model" OR "learning model"
```

OR "pedagogical model" OR "instructional strategy"  
OR "teaching strategy" OR "learning approach"  
OR intervention OR "problem-based learning"  
OR "project-based learning" OR "realistic mathematics education"  
OR STEM OR STEAM OR "cooperative learning"  
OR "collaborative learning" OR "blended learning")  
AND  
("secondary education" OR "secondary school"  
OR "middle school" OR "junior high school"  
OR "senior high school" OR adolescent  
OR "grade 7" OR "grade 8" OR "grade 9"  
OR "grade 10" OR "grade 11" OR "grade 12")

An additional search was conducted using backward citation tracking and forward citation tracking of studies that met the inclusion criteria. These techniques were employed to identify relevant studies that might not have been retrieved through the primary search strategy. Articles identified through citation tracking underwent the same screening and methodological quality assessment as those retrieved from the database searches.

### **Study Selection**

Records retrieved from Scopus and ERIC were combined into a single database and screened for duplicate publications. Duplicate records were identified and removed in several stages based on the DOI, normalized article title, author names, and publication year. The initial search yielded 95 records, comprising 57 records from Scopus and 38 records from ERIC. After removing 24 duplicate records, 71 unique records remained for the screening stage.

The selection process consisted of two stages. First, titles and abstracts were screened to determine their relevance to the review objectives. Second, the full texts of the remaining articles were assessed against the predefined inclusion and exclusion criteria. Reasons for exclusion at the full-text stage were recorded explicitly, including ineligible populations, outcomes unrelated to mathematical literacy, the absence of an instructional intervention involving students, or the lack of empirical data.

The screening process was conducted independently by two reviewers. Any disagreements were resolved through discussion until consensus was reached. When consensus could not be achieved, a third reviewer was consulted to make the final decision. Inter-rater agreement during the title and abstract screening stage was assessed using Cohen's kappa coefficient.

A summary of the study selection process is presented using the PRISMA 2020 flow diagram.

PRISMA Stage	Number of Articles
Records identified through Scopus	57
Records identified through ERIC	38
Total records identified	95
Duplicate records removed	24
Unique records screened (title and abstract)	71
Records excluded after title and abstract screening	<i>n</i> = ...
Full-text articles assessed for eligibility	<i>n</i> = ...
Full-text articles excluded, with reasons	<i>n</i> = ...
Studies included in the final synthesis	<i>n</i> = ...

### Methodological Quality Assessment

The methodological quality of the studies that passed the full-text screening stage was assessed using the Mixed Methods Appraisal Tool (MMAT), Version 2018. The MMAT was selected because the reviewed studies employed a variety of research designs, including qualitative research, randomized controlled trials, quasi-experimental studies, quantitative descriptive studies, and mixed-methods research (Hong et al., 2018).

The assessment began with two general screening questions: (1) whether the research questions were clearly stated and (2) whether the collected data were sufficient to address those research questions. Subsequently, each study was evaluated using five methodological criteria corresponding to its research design. Each criterion was rated as "Yes," "No," or "Can't tell."

Following the recommendations of the MMAT developers, methodological quality was not summarized into a single aggregate score because such scores may obscure important methodological limitations. Instead, the appraisal results are reported for each criterion and were considered during the interpretation of the review findings. No study was excluded solely because of one or more methodological limitations; however, these limitations were documented and taken into account during the synthesis.

### Data Extraction

Data from all studies meeting the inclusion criteria were extracted using a structured data extraction form. The extracted information included the following:

Category	Extracted Data
Study identification	Author(s), publication year, country, journal, and DOI
Educational context	School level, grade level, mathematics topic or subject

Participant characteristics	Number of students, age range, characteristics of the intervention and comparison groups
Research design	Experimental, quasi-experimental, qualitative, case study, mixed methods, or development research
Instructional model	Model name, pedagogical foundation, instructional procedures, and intervention duration
Instructional components	Contextual problems, collaboration, mathematical modeling, technology integration, project-based activities, reflection, and assessment
Research instruments	Mathematical literacy tests, rubrics, interviews, observations, questionnaires, or other instruments
Research findings	Changes in mathematical literacy, qualitative findings, effect sizes (when available), and study limitations
Quality appraisal	MMAT assessment results

Data extraction was conducted by one reviewer and independently verified by a second reviewer to minimize recording errors. Any discrepancies were resolved through discussion and re-examination of the original articles.

### **Data Analysis and Synthesis**

The extracted data were analyzed using both descriptive synthesis and thematic synthesis. Descriptive synthesis was used to summarize the distribution of studies according to publication year, country, educational level, research design, sample size, intervention duration, instructional model, and technology integration.

Thematic synthesis was employed to identify pedagogical patterns across the included studies. The analytical process was adapted from Thomas and Harden (2008) and involved three stages: (1) systematic coding of the extracted data; (2) grouping codes into descriptive themes; and (3) developing higher-order analytical themes. Initial coding focused on authentic contexts, problem-solving activities, mathematical modeling, project-based learning, collaboration, classroom discussion, reflection, technology integration, and assessment strategies. Additional themes were developed inductively whenever new patterns emerged from the selected studies.

A meta-analysis was not conducted because the review was not limited to a single instructional intervention or a common outcome measure. The included studies were expected to differ substantially in terms of instructional models, research designs, measurement instruments, and reporting formats. Therefore, quantitative findings are synthesized by describing the direction and consistency of the reported effects, while qualitative findings are used to explain implementation characteristics, strengths, and limitations of the instructional models.

## Reliability and Transparency of the Review Process

To ensure transparency, every stage of the review process was documented using an audit trail. This documentation included the search date, databases searched, search strategies, numbers of retrieved records, duplicate records, screening decisions, reasons for full-text exclusion, MMAT appraisal results, and data extraction tables. The complete search strategies and the PRISMA 2020 flow diagram are provided as supplementary materials.

Where feasible, the review protocol, data extraction form, methodological quality assessments, and the list of studies excluded at the full-text screening stage will be deposited in an open repository such as the Open Science Framework (OSF). Making these materials publicly available enhances the transparency, reproducibility, and future updating of the review by other researchers.

## 3. RESULTS AND DISCUSSION

### 3.1. Results

#### Study Selection

The literature selection process consisted of the identification, deduplication, title and abstract screening, eligibility assessment, and final study inclusion stages. The initial search of the Scopus and ERIC databases yielded 95 records. After removing 24 duplicate records, 71 unique articles remained for title and abstract screening.

The screening process was conducted based on the predefined eligibility criteria, including the target population, competency focus, instructional intervention, publication type, and publication period. A total of 41 articles were excluded at this stage. Most excluded studies did not evaluate instructional models implemented with secondary school students, did not assess mathematical literacy or numeracy literacy, involved populations outside secondary education, or were review or conceptual papers.

Thirty articles were retained for full-text eligibility assessment. At this stage, six articles were excluded because they did not adequately match the scope of the review. Two studies measured only numeracy skills or specific mathematical subskills without directly assessing mathematical literacy. One study involved a mixed population in which results for secondary school students could not be separated. One study focused on teachers, another adopted academic literacy as the primary outcome, and one synthesized a series of long-term studies involving heterogeneous participant groups. Consequently, 24 studies met all inclusion criteria and were included in the final review.

**Table 1. Summary of the Study Selection Process**

Selection Stage	Number of Articles
Records identified from Scopus and ERIC	95
Duplicate records removed	24

Unique records screened (title and abstract)	71
Records excluded after title and abstract screening	41
Full-text articles assessed for eligibility	30
Full-text articles excluded	6
Studies included in the final review	24

### Distribution of Publications by Year

The included studies were published between 2017 and 2026. The publication trend indicates a substantial increase in research during the last three years of the review period. Eighteen of the 24 studies (75%) were published between 2024 and 2026. The highest number of publications occurred in 2025, with seven studies, followed by six studies in 2024 and five studies in 2026. In contrast, relatively few studies were published during the earlier years.

**Table 2. Distribution of Studies by Publication Year**

Year	2017	2019	2021	2022	2023	2024	2025	2026	Total
Number of studies	1	1	1	1	2	6	7	5	24

### Distribution by Country and Educational Context

Nineteen studies (79.17%) were conducted in Indonesia, making it the dominant research context in the reviewed literature. Three studies were conducted in Thailand, and two in Türkiye. The reviewed studies involved students from middle school, junior high school, and senior high school. Among the studies reporting participant numbers in their abstracts, sample sizes ranged from 18 to 212 students.

**Table 3. Distribution of Studies by Country**

Country	Number of Studies	Percentage
Indonesia	19	79.17%
Thailand	3	12.50%
Türkiye	2	8.33%
Total	24	100%

### Research Design Characteristics

The reviewed studies exhibited considerable methodological diversity. Eleven studies employed experimental or quasi-experimental designs. Five studies adopted research and development (R&D) methodologies involving the implementation and evaluation of instructional models. Another five studies used design-based research or design research approaches. Two studies employed mixed-methods intervention designs, while one study adopted a descriptive qualitative approach to examine the implementation of an instructional model in a specific educational context.

**Table 4. Distribution of Studies by Primary Research Design**

Primary Research Design	Number of Studies
Experimental or quasi-experimental	11
Research and development with implementation	5
Design-based research or design research	5
Mixed-methods intervention	2
Descriptive qualitative implementation study	1
Total	24

### Patterns of Instructional Models

The synthesis revealed that instructional approaches for developing mathematical literacy were highly diverse, with many studies combining multiple instructional strategies. The most frequently identified characteristic was the use of contextual, authentic, or culturally relevant problems, which appeared in 15 studies. The contexts included everyday situations, local environments, carbon emissions, public transportation, traditional foods, healthy menu planning, and chemistry-related problems.

Project-Based Learning (PjBL) and Problem-Based Learning (PBL) approaches appeared in eight studies. This category also included STEAM-based Project-Based Learning, Ethno-Project-Based Learning, and project-based blended learning. Likewise, digital technology integration was reported in eight studies, involving the use of GeoGebra, STEM Trails applications, e-modules, virtual reality, digital gamification, and information and communication technology (ICT)-supported learning.

Eight studies integrated STEM, STEAM, or other interdisciplinary learning approaches. Five studies implemented Realistic Mathematics Education (RME), Indonesian Realistic Mathematics Education (PMRI), or related variations. These included Virtual Realistic Mathematics Education, Ethno-Realistic Mathematics Education, STEM-RME, PMRI using the Palembang Light Rail Transit (LRT) context, and the integration of RME with the DAPIC problem-solving process.

**Table 5. Patterns of Instructional Models Identified**

Instructional Model Pattern	Number of Studies
Contextual, authentic, or culturally relevant problems	15
Project-Based Learning or Problem-Based Learning	8
Digital technology integration	8
STEM, STEAM, or interdisciplinary learning	8
RME, PMRI, or variations of realistic mathematics education	5

*Note.* The categories shown in table 5 are not mutually exclusive. A single study may be classified into more than one category.

### **Reported Learning Outcomes**

Most studies reported improvements in students' mathematical literacy or numeracy following the implementation of instructional models. Sumirattana et al. (2017) found that integrating Realistic Mathematics Education (RME) with the DAPIC problem-solving process improved the mathematical literacy of Grade 9 students. Çakıroğlu et al. (2024) reported improvements in the formulate, employ, and interpret dimensions of mathematical literacy through Virtual Realistic Mathematics Education. Similarly, Srikoon et al. (2024) demonstrated that the STEMEN model produced higher levels of mathematical literacy and problem-solving performance than the 5E instructional model.

Within project-based learning approaches, Putri et al. (2021) developed a healthy menu project to address numeracy problems related to students' daily calorie requirements. Supianti et al. (2025) reported improvements in mathematical literacy through STEAM-based Project-Based Learning. Technology-enhanced instruction was also evident in the studies by Cahyono et al. (2025), who implemented digital application-based math trails, and Maysarah et al. (2026), who employed Ethno-Project-Based Learning supported by GeoGebra.

However, not all studies reported consistent findings. Utari et al. (2019) found that although students in the Situation-Based Learning group showed improved problem-solving skills, their gains in mathematical literacy were not significantly different from those of students receiving expository instruction. In addition, Amarta and Putri (2023) focused primarily on describing students' numeracy skills through PMRI using the Palembang LRT context, rather than comparing the effectiveness of instructional models.

Overall, the review indicates that research on mathematical literacy in secondary education has explored a broad range of contextual, realistic, project-based, problem-based, interdisciplinary, collaborative, and technology-enhanced instructional models. The variations in instructional approaches, research designs, and reported outcomes are examined in greater depth in the Discussion section.

## **3.2 Discussion**

### **Shifting Mathematics Instruction from Procedural Mastery to Contextual Mathematical Literacy**

The findings of this review indicate that the development of mathematical literacy in secondary education extends beyond students' mastery of formulas and computational procedures. Most instructional models identified in the reviewed studies place students in situations that require them to use mathematics to understand problems, construct representations, select appropriate strategies, and interpret solutions. Of the 24 studies included in this review, 15 incorporated contextual, authentic, or culturally relevant problems as central components of instruction. This pattern is consistent with the PISA 2022 framework, which defines

mathematical literacy as the capacity to reason mathematically and to formulate, apply, and interpret mathematics in a variety of real-world contexts (OECD, 2023).

These findings suggest that context should not be viewed merely as a narrative element embedded in mathematical problems. Rather, context serves as the starting point of the mathematization process. Students are required to identify relevant information, connect real-world situations with mathematical concepts, perform calculations or develop mathematical models, and evaluate whether their solutions are reasonable. For example, Sumirattana et al. (2017) integrated Realistic Mathematics Education (RME) with the DAPIC problem-solving process to enhance secondary students' mathematical literacy. Their approach positioned authentic real-life problems as a bridge between students' prior experiences and the formalization of mathematical concepts.

A similar pattern was identified in studies conducted in Indonesia. Putri et al. (2021) developed a healthy menu project that linked mathematics to calculations involving Body Mass Index (BMI), Basal Metabolic Rate (BMR), and daily caloric requirements. Likewise, Amarta et al. (2023) employed the Palembang Light Rail Transit (LRT) system as a context for learning the Cartesian coordinate system. Both studies demonstrate that contexts closely related to students' everyday experiences can help reduce the gap between school mathematics and real-world applications. Nevertheless, contextualization should remain focused on promoting mathematical reasoning. Contexts that merely decorate textbook problems without engaging students in meaningful mathematical modeling risk becoming superficial variations that do little to improve the quality of learning.

#### Problem-Based and Project-Based Learning as Opportunities to Use Mathematics

Eight studies included in this review implemented Problem-Based Learning (PBL), Project-Based Learning (PjBL), or combinations of these approaches. This finding indicates that problem-based and project-based instruction represents one of the most widely adopted pathways for developing mathematical literacy. These instructional models provide students with opportunities to engage in mathematical thinking at a level beyond routine procedural exercises. Students are expected to understand complex problems, gather relevant information, determine appropriate solution strategies, complete authentic tasks, communicate their findings, and evaluate their solutions.

Project-Based Learning is also frequently integrated with interdisciplinary approaches. Supianti et al. (2025), for example, implemented STEAM-based Project-Based Learning to promote both mathematical literacy and character development. Within this framework, mathematics is not taught as an isolated discipline but is integrated with science, technology, engineering, and the arts to develop meaningful solutions or products. Such integration is highly relevant to mathematical literacy

because students must determine when mathematical concepts should be applied and how computational results should be interpreted within specific contexts.

Srikoon et al. (2024) proposed a more specialized approach through the STEMEN model, which integrates STEM education with educational neuroscience. Their findings indicated that STEMEN produced higher levels of mathematical literacy and problem-solving performance than the 5E instructional model within the context of their study. Similarly, Cahyono et al. (2025) developed STEM instruction through technology-supported math trails, in which students explored their surrounding environment to solve mathematical problems. In this approach, mathematics was learned through observation, measurement, mathematical modeling, and interpretation.

Nevertheless, adopting labels such as PBL, PjBL, STEM, or STEAM does not automatically guarantee improvements in mathematical literacy. One study included in this review found that although Situation-Based Learning improved students' problem-solving skills, gains in mathematical literacy were not significantly different from those achieved through expository instruction. This finding highlights that instructional effectiveness depends not only on the instructional model itself but also on the quality of learning tasks, the duration of implementation, students' level of engagement, teacher support, and the appropriateness of the assessment instruments.

### **Technology Integration Should Be Grounded in Pedagogical Principles**

Eight studies incorporated digital technology into mathematics instruction aimed at developing mathematical literacy. The technologies included GeoGebra, e-modules, virtual reality, GPS-based applications for math trails, digital gamification, and various information and communication technology (ICT)-based learning tools. These findings suggest that digital technologies are increasingly being used to enrich students' mathematical learning experiences.

Çakıroğlu et al. (2024) developed Virtual Realistic Mathematics Education, which combines virtual learning environments with the principles of RME. Their study reported improvements in the formulate, employ, and interpret dimensions of mathematical literacy, although gains in the interpretation dimension were comparatively smaller. These findings suggest that technology can effectively support students in exploring mathematical representations and problem situations. However, interpreting mathematical results still requires explicit instructional attention. Students should not only produce computational results or visual representations but also explain the meaning of those results within the context of the problem.

Komarudin et al. (2024) presented a different perspective through the Reading, Mind Mapping, and Sharing (RMS) model combined with brainstorming techniques. Rather than positioning technology as the focal point of instruction, this model integrated digital literacy with reading activities, idea organization,

collaborative discussion, and the communication of findings. Similarly, Dewi and Maulida (2023) developed STEM-oriented instructional materials through the ICT-assisted Preprospec Learning Model. Together, these studies suggest that technology becomes more meaningful when it supports well-defined cognitive processes and purposeful learning interactions.

Therefore, technology should not be regarded as a stand-alone solution for improving mathematical literacy. Instead, digital tools should be selected to address specific pedagogical needs, such as clarifying abstract representations, enabling data exploration, providing simulation experiences, supporting collaborative learning, or connecting mathematics with students' everyday environments. Furthermore, successful technology integration requires consideration of teachers' readiness, the availability of digital devices, internet accessibility, and disparities in technological resources across schools. Without these supporting conditions, digital innovations may be difficult to implement consistently and effectively.

### **RME, PMRI, and Local Contexts as Recurring Patterns**

Five studies included in this review implemented Realistic Mathematics Education (RME), Indonesian Realistic Mathematics Education (PMRI), or other variations of realistic mathematics education. This recurring pattern suggests that the principles of realistic mathematics education continue to play an important role in research on mathematical literacy. RME extends beyond the use of everyday problems; it emphasizes a gradual progression from students' informal understanding toward increasingly formal mathematical representations and concepts.

Sumirattana et al. (2017) demonstrated that integrating RME with the DAPIC problem-solving process provides a structured approach to developing students' mathematical literacy. In the Indonesian context, PMRI has been implemented through learning activities based on situations familiar to students, such as public transportation, healthy menu planning, and local cultural practices. Such approaches are particularly relevant because mathematical literacy requires students to apply mathematics in situations that are meaningful within their own experiences.

The use of culturally relevant contexts has also become increasingly prominent. Several studies incorporated ethnomathematics, traditional foods, or local cultural settings into Project-Based Learning (PjBL), flipped classrooms, RME, and technology-enhanced learning. Integrating local contexts can increase the relevance of mathematics instruction and help students recognize that mathematics is closely connected to social and cultural practices. Nevertheless, culturally based instructional models require careful design. Cultural elements should have explicit connections to mathematical concepts and instructional objectives. Using cultural contexts merely as decorative features without engaging students in meaningful mathematization is unlikely to enhance mathematical literacy.

### **Research Design Variations and Strength of Evidence**

The reviewed corpus included 11 experimental or quasi-experimental studies, five research and development studies involving implementation, five design-based research or design research studies, two mixed-methods intervention studies, and one descriptive qualitative study. This methodological diversity provides a broad perspective on how instructional models have been developed and evaluated. Experimental and quasi-experimental studies facilitate comparisons between instructional approaches, while development studies provide insights into the design and refinement of instructional models and learning materials. Design-based research, in contrast, offers a deeper understanding of learning trajectories and students' responses to specific instructional contexts.

However, this methodological heterogeneity also limits the ability to conclude that one instructional model is inherently superior to another. The included studies differed considerably in sample size, intervention duration, mathematics content, grade level, measurement instruments, and outcome indicators. While some studies directly assessed mathematical literacy, others focused on numeracy literacy, numeracy skills, or mathematical spatial literacy. These variations should be considered carefully when interpreting the overall findings.

Another limitation concerns the geographical distribution of the evidence. Nineteen of the 24 studies were conducted in Indonesia. Although this concentration strengthens the relevance of the review for the Indonesian educational context, it also limits the generalizability of the findings across countries. Differences in curriculum structures, school characteristics, technological readiness, learning cultures, and teacher competencies may influence the effectiveness of instructional models in different educational systems. Therefore, the findings of this review should be interpreted as an overview of current research trends rather than as evidence supporting a universally applicable instructional model.

Furthermore, 18 of the 24 studies were published during the period 2024–2026, reflecting growing scholarly interest in mathematical literacy, technology integration, and contextual learning. However, the recent nature of much of the available literature also means that evidence regarding the consistency of outcomes, long-term sustainability, and lasting educational impacts remains limited. Many studies were conducted within a single school, a single group of students, or relatively short intervention periods.

### **Implications for Mathematics Instruction in Secondary Education**

The findings of this review suggest that fostering mathematical literacy requires instructional designs that engage students throughout the entire process of applying mathematics. Mathematics teachers should design learning experiences that extend beyond obtaining correct answers by encouraging students to explain how they understand problems, formulate assumptions, select appropriate

strategies, use mathematical representations, and evaluate the reasonableness of their solutions.

Instructional models should be selected according to instructional objectives, student characteristics, curriculum content, and available school resources. RME and PMRI can be employed to strengthen the connection between mathematical concepts and authentic experiences. Problem-Based Learning (PBL) and Project-Based Learning (PjBL) are particularly appropriate when students are expected to solve open-ended problems or develop meaningful products. STEM and STEAM approaches provide opportunities to integrate mathematics with other disciplines, while digital technologies should be adopted when they offer clear pedagogical benefits, such as supporting simulation, visualization, environmental exploration, or information management.

The review also highlights the importance of instructional scaffolding. Authentic problems are often substantially more complex than routine classroom exercises, requiring students to receive gradual support as they identify relevant information, construct mathematical models, and justify their conclusions. Collaborative discussion, brainstorming, guiding questions, mind mapping, and reflective activities can help students develop effective problem-solving strategies. Within this instructional framework, the teacher's role shifts from transmitting procedures to facilitating students' mathematical thinking.

### **Future Research Directions**

This review identifies several areas that warrant further investigation. Future studies should evaluate instructional models across a wider range of educational settings, including schools with limited access to digital technologies and schools located outside urban areas. Multi-site studies are particularly important to ensure that research findings represent broader educational contexts rather than individual classrooms or schools.

Future research should also report mathematical literacy outcomes in greater detail. Assessments should distinguish among the formulate, employ, interpret, and evaluate dimensions of mathematical literacy. Reporting should also include effect sizes, intervention duration, implementation fidelity, teacher characteristics, and levels of student engagement. Such information would facilitate more accurate comparisons across studies.

Longitudinal research is also needed to determine whether improvements in mathematical literacy are sustained after instructional interventions have ended. Further investigations should examine issues related to technological accessibility, teachers' workload, curriculum adaptation, and the scalability of instructional models. In this way, future research can move beyond evaluating isolated instructional innovations and contribute to sustainable improvements in mathematics education.

Overall, this review demonstrates that mathematical literacy develops most effectively when students are provided with meaningful opportunities to use mathematics in authentic problem situations. Contextual, problem-based, project-based, realistic, interdisciplinary, collaborative, and technology-enhanced instructional models all show considerable potential to support this process. Nevertheless, the quality of implementation remains a critical determinant of success. The selection of instructional models should therefore take into account instructional objectives, teacher preparedness, student characteristics, and school contexts. Consequently, promoting mathematical literacy does not require a single universal instructional model but rather thoughtfully designed, context-sensitive instructional practices that can be systematically evaluated and continuously improved.

## **CONCLUSION**

This systematic literature review demonstrates that improving mathematical literacy among secondary school students does not depend on a single instructional model but rather on the extent to which instructional approaches engage students in using mathematics within meaningful contexts. Among the 24 studies included in this review, the use of contextual, authentic, and culturally relevant problems emerged as the most common instructional characteristic. In addition, Problem-Based Learning (PBL), Project-Based Learning (PjBL), STEM/STEAM-based approaches, digital technology integration, and Realistic Mathematics Education (RME) were identified as the instructional models most frequently employed to foster students' mathematical literacy.

Overall, most studies reported positive effects on students' mathematical literacy, particularly when instruction provided opportunities for mathematical modeling, problem-solving, collaboration, reflection, and the interpretation of mathematical results in authentic contexts. These findings suggest that the development of mathematical literacy requires instructional designs that emphasize students' active engagement in mathematical thinking and the functional application of mathematics, rather than focusing solely on procedural proficiency.

Nevertheless, this review also identified several limitations, including the predominance of studies conducted in Indonesia, the considerable methodological diversity across studies, and the limited availability of research examining the long-term effects of instructional interventions. Therefore, future research should investigate instructional models across more diverse educational settings, employ longer intervention periods, and report mathematical literacy outcomes in greater detail. Such efforts will provide more robust evidence regarding the effectiveness of different instructional models in enhancing students' mathematical literacy.

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