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# Pedagogical Interventions for Enhancing Students' Mathematical Literacy: A Systematic Literature Review

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**Annotation.** This review examines pedagogical interventions to enhance mathematical literacy in Indonesia. It analyses research trends, objectives, types and characteristics of interventions, and the teachers' roles. Thirty articles were selected using PRISMA protocol. The review identifies research trends across several aspects. Six intervention types and six teacher roles were identified. Each plays a key role in supporting students' mathematical literacy. Future research directions are also discussed.

**Keywords:** *instructional approach, learning media, pedagogical interventions, pedagogical model, mathematical literacy.*

## Introduction

Mathematical literacy has been recognised as a critical competency for individuals in the 21st century. It enables individuals to effectively use mathematical understanding and reasoning to address real-world problems (Komarudin et al., 2024; Sumirattana et al., 2017). Defined as individuals' aptitude to formulate, employ, and interpret mathematics

in diverse practical contexts (OECD, 2023a), mathematical literacy transcends computational skills, emphasizing the application of mathematics in real-life experiences (Jablonka, 2015). It involves the ability to model the problem mathematically, using mathematical knowledge and skills to solve the problem and evaluating the solution to the problem. Mathematical literacy equips students with essential conceptual and practical skill sets for real-life problem solving (Marciniak, 2015; OECD, 2023a; Sumirattana et al., 2017).

Mathematical literacy has become a central and fundamental competency in school curricula and instructional design worldwide. In Indonesia, the curriculum emphasizes mathematical literacy as a key learning objective in both the 2013 curriculum and the "Merdeka" curriculum. The Minimum Competency Assessment (MCA) also assesses students' mathematical literacy from elementary to high school to evaluate the quality of education in Indonesia (Ministry of Education and Culture of Indonesia, 2019). However, the Programme for International Student Assessment (PISA) reported that mathematical literacy score of Indonesian students is still low (OECD, 2023b). The lack of Indonesian students' mathematical literacy was also reflected in the National Assessment report (Zamjani et al., 2024). Moreover, previous studies revealed the difficulties of Indonesian students across the provinces and educational levels in solving mathematical literacy problems (Ekawati et al., 2020; Harisman et al., 2023; Heryani et al., 2023; Rahmawati et al., 2023; Rum & Juandi, 2022; Runtu et al., 2023; Yustitia et al., 2022).

Mathematical literacy is an essential ability for individuals to deal with real-world problems. Being mathematically literate means being able to solve practical problems and make reasonable decisions. Mathematical literacy is not just a competency bound to mathematics learning activities in the classroom. It also reaches out to different fields of science and enables individual to solve practical problem in diverse areas beyond abstract and formal mathematics (Gravemeijer et al., 2017; van der Wal et al., 2017). This means mathematical literacy is not only limited to a calculation procedure. In addition, improving mathematical literacy relates to a process of developing reasoning and creative thinking of individuals. Unfortunately, the implementation of mathematics teaching in Indonesia still emphasizes on strengthening memorization and procedural skills rather than conceptual understanding and mathematical reasoning (Sukarya & Isnurani, 2023; Sumirattana et al., 2017). In addition, it remains classical issues regarding the lack of teachers' ability to design and employ pedagogical intervention focused on enhancing students' mathematical literacy (Bolstad, 2023).

Addressing the lack of Indonesian students' mathematical literacy is crucial for improving the performance on the PISA ranking and achieving national education objectives. It can be addressed by bridging the gap between educational policy and practice. Prior studies have explored pedagogical intervention for enhancing students' mathematical literacy (Hiebert & Grouws, 2007; Profke, 2014; Steen et al., 2007). Many researchers in Indonesia employed different kinds of interventions such as instructional

approaches (Fauzana et al., 2020), methods (Kartini et al., 2021), models (Zaenuri et al., 2020), strategies (Utari et al., 2019), media (Gustiningsi et al., 2024), and teaching materials (Dewi & Maulida, 2023). The studies indicate the effectiveness of the intervention for enhancing students' mathematical literacy. However, there remains a lack of consensus about the most effective intervention for improving students' mathematical literacy (Schoenfeld, 2014). Prior studies also tend to emphasize the statistical impact of the interventions without discussing the characteristics of the interventions in improving students' mathematical literacy. In addition, the existing studies also rarely address the role of teachers in designing and implementing pedagogical interventions for enhancing mathematical literacy.

This study employs a systematic literature review (SLR) to synthesize evidence from empirical studies in Indonesia about pedagogical interventions used to enhance students' mathematical literacy. This SLR aims to analyse: (1) the trends of research about pedagogical interventions for enhancing mathematical literacy, (2) the objectives of research in this topic, (3) the types and characteristics of effective interventions, and (4) the role of teachers in designing and implementing these interventions. Therefore, this SLR concerns answering the following research questions.

1. What are the research trends of pedagogical interventions to enhance mathematical literacy, particularly in terms of publication year, methodological approaches, mathematics content, location of study, and subject educational levels?
2. What are the primary objectives of studies about pedagogical interventions for enhancing students' mathematical literacy?
3. What are the types and characteristics of the interventions used to enhance students' mathematical literacy?
4. What is the teacher's role in designing, implementing, and adapting the interventions for enhancing mathematical literacy?

## Method

A systematic literature review (SLR) guided by the PRISMA protocol was employed in this study (Page et al., 2021). This method offers an appropriate framework for analysing and synthesizing previous studies in a transparent, rational, and reproducible process (Putra et al., 2023). It offers a systematic and standardized model and framework for researchers to search, screen, extract, and analyse studies from various specified databases. This SLR aimed to explore empirical studies on pedagogical interventions designed to enhance students' mathematical literacy.

The researchers examine several inclusion/exclusion criteria to filter and restrict the studies included in this SLR. The inclusion/exclusion criteria were developed through an extensive discussion among researchers. The inclusion criteria consist of: (1) the studies

were conducted in Indonesia between 2019 and April 2024, (2) the studies were published in scientific and reviewed journals or conference proceedings, (3) the studies were published in open-access journals or proceedings and written in English, (4) the studies focused on interventions to enhance mathematical literacy, and (5) the studies provide qualitative or quantitative data on the intervention outcomes. In addition, articles that did not match the inclusion criteria were excluded from the review.

Following PRISMA guidelines (Page et al., 2021), the study adhered to five stages: identification, screening, eligibility assessment, data extraction, and analysis (Figure 1). During the identification stage, search strings were tailored to each database using Boolean operators (AND/OR) and keywords aligned with the inclusion criteria. Scopus, ScienceDirect, ERIC, AIP Publishing, and IOP Science databases were used for collecting the studies. The initial search yielded 409 articles across five databases. Table 1 summarizes the search strings and results per database.

During screening, *Covidence* software was used to manage the study selection process. All 409 studies were imported to the *Covidence* and 8 studies were detected. After that, the researcher screened 401 remaining studies, which resulted in 270 excluded studies due to irrelevant titles and abstracts. There remain 131 studies eligible for the next stages.

During the eligibility assessment, 131 studies underwent full-text review, resulting in 30 included studies. Exclusions (n = 101) were due to irrelevant outcomes (n = 67), mismatched intervention (n = 16), studies outside Indonesia (n = 9), irrelevant study design (n = 7), and incorrect settings (n = 2).

Data coding, extraction, and quality assessment were conducted using *Covidence*. It was conducted by developing and establishing several categories to extract the data as well as a quality assessment template. Each data point was coded and classified by themes for each category that has been established. It helps the researchers in analysing and synthesizing data. Quality assessment criteria included relevance to the research questions, methodological clarity, validity of results, and significance of contributions. After that, all 30 included studies were analysed qualitatively according to the classification of categories and themes. In addition, synthesis of the data is conducted to answer the research question and give insight for future research regarding pedagogical intervention in enhancing students' mathematical literacy.

**Figure 1**

*PRISMA Procedure Diagram*

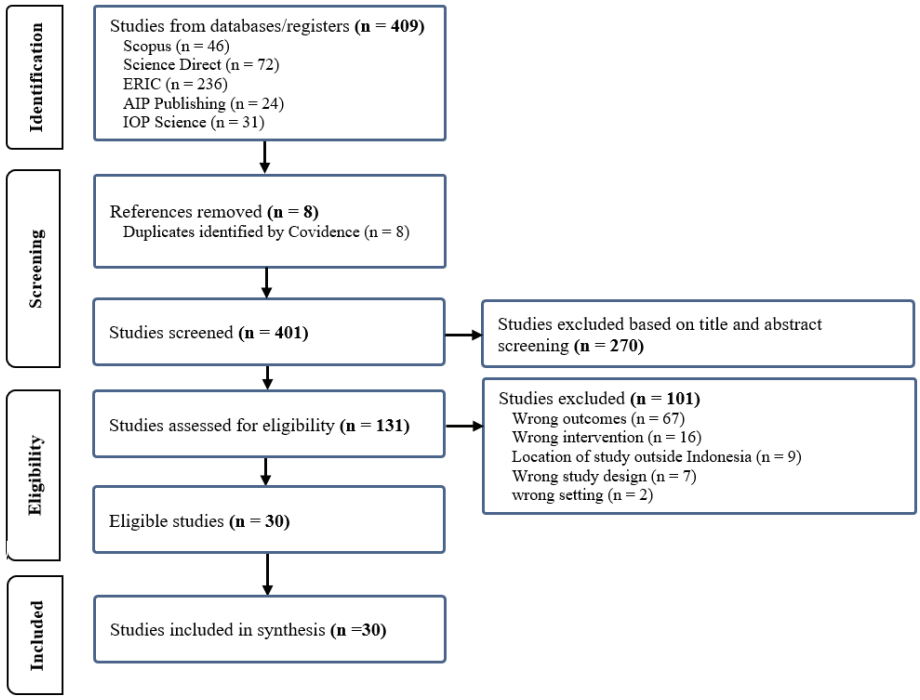


**Table 1**

*Database and Keywords Used for Searching Data*

| Database | Keyword | Results |
|---|---|---|
| **Scopus** | "Mathematical literacy" AND "learning model" OR "learning method" OR "learning approach" OR "learning strategy" OR "learning instruction" | 46 |
| **ScienceDirect** | "Mathematical literacy" AND "learning model" OR "learning method" OR "learning approach" OR "learning strategy" OR "learning instruction" | 72 |
| **ERIC** | "Mathematical literacy" OR "learning model" OR "learning method" OR "learning approach" OR "learning strategy" OR "learning instruction" | 263 |
| **AIP Publishing** | "Mathematical literacy" AND "learning model" OR "learning method" OR "learning approach" OR "learning strategy" OR "learning instruction" | 24 |
| **IOP Science** | "Mathematical literacy" AND "learning model" OR "learning method" OR "learning approach" OR "learning strategy" OR "learning instruction" | 31 |

## Results and Discussion

The analysis of 30 selected studies reveals critical insight into pedagogical intervention for enhancing mathematical literacy. Subsequent subsections present trends in publication year, methodology, mathematics content, location of study, and subject educational level. In addition, the finding also provides the research objectives of the studies regarding this topic. After that, it presents the type and characteristics of the intervention used in the studies and discusses how these interventions enhance students' mathematical literacy. Finally, it discusses teachers' role in the design, implementation, and adaptation of pedagogical intervention aimed at enhancing mathematical literacy.

### *Trends of The Studies*

The trends of the studies in terms of publication year, methodology, mathematics content, location of study, and subject educational level are presented in Table 2. Most articles were published in 2023 (n = 9), with the fewest in 2022 (n = 2). Despite fluctuations, the annual publication count shows a gradual upward trend from 2019 to April 2024. Quantitative methods dominated (n = 15), primarily employing quasi-experimental designs (e.g., pretest-post-test with non-equivalent control groups). Other methodologies included qualitative methods (n = 2), developmental studies (n = 3), research and development (n = 5), mixed methods (13%, n = 4), and action research (n = 1). Geometry and measurement were the most frequently addressed content areas (n = 10), while data and uncertainty were the least explored (n = 1). The rest of the studies are conducted for numbers content, algebra content, and some of the studies did not specify the mathematics content used in the study.

This trend reflects the growing recognition of mathematical literacy as a critical competency in the 21st century (İlhan & Aslaner, 2021; OECD, 2023a; Sümen & Çalışıcı, 2016) and a fundamental competency in Indonesia's Curriculum (Ministry of Education and Culture of Indonesia, 2020; Rawani et al., 2024). The preference for quantitative methods, particularly quasi-experimental designs, reflects the field's emphasis on evaluating the effectiveness of interventions (Creswell, 2014; Fraenkel & Wallen, 2009). In addition, the low mathematical literacy achievement of Indonesian students also motivates research related to the design and application of various pedagogical interventions to improve students' mathematical literacy skills (Fauzana et al., 2020; Gustiningsi et al., 2024)2.

Junior high school students were the primary focus (n = 17), whereas elementary (n = 4), senior high school (n = 5), and university levels (n = 4) were underrepresented. This distribution indicates that the junior high school level is considered as critical stages for developing students' mathematical literacy (Rachmaningtyas et al., 2022; Sumirattana et al., 2017). It aligns with the framework of PISA which also assessed

students' mathematical literacy in the same stages (OECD, 2023a). It also suggests the need for more research across all educational level.

**Table 2**
*Trend of Selected Studies According to Categories*

| Category | N | % | Category | n | % |
|---|---|---|---|---|---|
| **Publication Year** | | | **Location of Studies** | | |
| 2019 | 5 | 16,7 | West Java | 7 | 23,3 |
| 2020 | 5 | 16,7 | Central Java | 5 | 16,7 |
| 2021 | 5 | 16,7 | East Java | 4 | 13,3 |
| 2022 | 2 | 6,7 | South Sumatera | 3 | 10,0 |
| 2023 | 9 | 30,0 | Jakarta | 2 | 6,7 |
| 2024 | 4 | 13,3 | Bengkulu | 1 | 3,3 |
| **Method** | | | West Kalimantan | 1 | 3,3 |
| Quantitative | 15 | 50,0 | Yogyakarta | 1 | 3,3 |
| Qualitative | 2 | 6,7 | Banten | 1 | 3,3 |
| Developmental Study | 3 | 10,0 | Bali | 1 | 3,3 |
| Research & Development | 5 | 16,7 | North Sulawesi | 1 | 3,3 |
| Mixed Method | 4 | 13,3 | North Sumatera | 1 | 3,3 |
| Action Research | 1 | 3,3 | Lampung | 1 | 3,3 |
| **Mathematics Content** | | | South Sulawesi | 1 | 3,3 |
| Numbers | 6 | 20,0 | **Subject Level** | | |
| Algebra | 4 | 13,3 | Elementary School | 4 | 13,3 |
| Data & Uncertainty | 1 | 3,3 | Junior High School | 17 | 56,7 |
| Geometry & Measurement | 10 | 33,3 | Senior High School | 5 | 16,7 |
| Unspecified | 9 | 30,0 | University | 4 | 13,3 |

The majority of the studies were published in Scopus-indexed conference proceedings, particularly in the Journal of Physics: Conference Series and AIP Conference Proceedings. It indicates a strong focus to present the research findings at academic conferences. However, a smaller proportion of studies were published in Scopus-indexed journals, such as the Journal on Mathematics Education, suggesting a need for more high-impact journal publications to advance the field.

All studies were conducted in Indonesia, with 67% (n = 20) concentrated in Java (e.g., West Java, Central Java). It shows that research related to pedagogical interventions for enhancing mathematical literacy has not been conducted evenly distributed across all provinces in Indonesia. Furthermore, it reflects that research on this topic in Eastern provinces of Indonesia was unrepresented. Consequently, it leads to

geographic bias and limited generalizability of the research results. In addition, the dominant portion of the studies in Java indicates disparities in research infrastructure and funding that requires policy interventions to ensure equitable research implementation throughout Indonesia, particularly in Eastern Indonesia (Rayhan & Juandi, 2023).

### *The Objectives of Studies*

The reviewed studies demonstrated three primary research objectives, as presented in Table 3. Most studies (n = 20) evaluated the effectiveness of pedagogical interventions on mathematical literacy. Some of these studies focused on assessing students' mathematical literacy after giving an intervention and comparing it with students' initial mathematical literacy. For example, the Discovery Learning (DL) model significantly improved mathematical literacy among junior high school students (Rahmadani et al., 2022), while the Higher Order Thinking Skills (HOTS) problem worksheet significantly improved university students' mathematical literacy (Prastiti et al., 2020). The rest of these studies compared students' mathematical literacy between the experiment and control class to evaluate the interventions' effectiveness. The results of these studies confirmed that students' mathematical literacy in the experiment class was significantly better than in the control class. For example, Utari et al. (2019) found the SBL strategy to be better than expository instruction. Meanwhile, Pujiastuti & Haryadi (2023)use and interpret mathematics in various contexts. The aim of this research is to determine the effectiveness of Guided Inquiry Learning-Augmented Reality (GILAR determined the Guided Inquiry Learning with Augmented Reality (GILAR) as a better intervention than the direct instruction model. Both studies offer effective pedagogical intervention to improve students' mathematical literacy. Although, several challenges may be encountered when implementing these interventions, including teacher readiness, infrastructure support, and technological access (Fullan & Langworthy, 2014).

**Table 3**
*Objectives of Sample Studies*

| Source | Research objective | | |
|---|---|---|---|
| | **Effectiveness evaluation** | **Development** | **Post-intervention analysis** |
| Dewi & Maulida, 2023 | | v | |
| Fauzana et al., 2019 | v | | |
| Hafiz et al., 2020 | v | | |
| Jayanti et al., 2024 | | v | |
| Kartini et al., 2021 | v | | |
| Machromah et al., 2021 | | v | |
| Maslihah et al., 2021 | v | | |

| Source | Research objective | | |
|---|---|---|---|
| | Effectiveness evaluation | Development | Post-intervention analysis |
| Maulana et al., 2019 | v | | |
| Nurmasari et al., 2024 | | v | |
| Prastiti et al., 2020 | v | | |
| Pujiastuti & Haryadi, 2023 | v | | |
| Apsari et al., 2023 | | | v |
| Salsabila et al., 2020 | v | | |
| Sari et al., 2022 | v | | |
| Septiyana et al., 2019 | v | | |
| Shodiq & Rokhmawati, 2021 | | v | |
| Susanta et al., 2023 | | v | |
| Utari et al., 2019 | v | | |
| Wesna et al., 2021 | v | | |
| Yaniawati et al., 2023 | | v | |
| Zaenuri et al., 2020 | v | | |
| Supriadi et al., 2023 | v | | |
| Susanti et al., 2023 | v | | |
| Rahmadani et al., 2022 | v | | |
| Djam'an et al., 2023 | | v | |
| Domu et al., 2023 | v | | |
| Gustiningsi et al., 2024 | | | v |
| Rawani et al., 2024 | v | | |
| Pradana et al., 2020 | v | | |
| Umbara & Nuraeni., 2019 | v | | |

Several studies (n = 8) employed developmental research to develop learning products for facilitating students' mathematical literacy. Five of these studies focused on assessing the validity, practicality, and effectiveness of the developed interventions. The developed products consist of different kinds of interventions such as teaching materials (Dewi & Maulida, 2023), pedagogical models (Djam'an et al., 2023; Nurmasari et al., 2024; Shodiq & Rokhmawati, 2021)therefore, require an appropriate learning model to improve their mathematical literacy. This research aims to develop a learning model, termed Realistic Mathematics Engineering (RMEng, and ICT-based learning media (Yaniawati et al., 2023). The studies presented here tested innovative interventions that immerse students in relevant context, in so doing, improve their mathematical literacy. The works reflect an adaptation to context very relevant for mathematics education reform (Anderson & Shattuck, 2012). The works also demonstrate the effectiveness of designing and implementing interventions that feature mathematical tasks grounded in students' cultural experiences

(Gravemeijer et al., 2017). In addition, the studies also show the potential impact of integrating technology into the pedagogical interventions which aligns with Technological, Pedagogical, Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) There are three studies focused on evaluating the validity, practicality, and potential effect of the developed interventions. These studies developed students worksheets in the form of PISA-based numeracy problem (Jayanti et al., 2024), PISA-like problem with batik context (Machromah et al., 2021), and mathematical literacy task using Bengkulu context (Susanta et al., 2023). These studies concerned producing innovative and potentially effective students' worksheets to enhance students' mathematical literacy. However, it emphasized validity, practicality, and the potential effect of the developed product in the small class instead of evaluating long-term and large class effectiveness. This contradicts to the McKenney and Reeves (2012) idea of rigorous evaluation to ensure the quality and scalability of developed product.

The remaining 2 studies used qualitative methods to analyse students' mathematical literacy in solving problems aligned with OECD's framework (OECD, 2023a) after given a certain intervention. Apsari et al. (2023) conducted a qualitative experiment to analyse students' mathematical literacy after giving different ways of conducting lessons on two-digits multiplication for primary school students. The role of digital tool to enhance students' mathematical literacy was also analysed in the study of Gustiningsi et al. (2024). These studies incorporated students' social context in the pedagogical interventions, which enables students to learn the abstract concept in more relevant way. This aligns with Schoenfeld's (2016) study which emphasizes the importance of using authentic and real-world tasks for enhancing students' mathematical literacy. In addition, it relates to the situated cognition theory, which perceives learning as an activity that cannot be separate from students' social context (Brown et al., 1989).

A critical gap, however, lies in the limited attention to affective dimensions (e.g., motivation, anxiety, self-efficacy) in these analyses. While cognitive outcomes were extensively documented, only a few studies gave attention to affective dimensions (Utari et al., 2019). The lack of attention to the affective dimensions contrasts with the perspective for holistic assessments of mathematical literacy (Hannula et al., 2019).

### *Types of Interventions Used in the Studies*

This systematic review identified six categories of pedagogical interventions, as presented in Table 4. The reviewed studies utilized six primary types of intervention: pedagogical models (e.g., PBL, DL), approaches (e.g., RME), strategies (e.g., cognitive conflict), ICT-based media (e.g., VMK), students' worksheets (e.g., ethnomathematics-based PISA-like problems), and teaching materials (e.g., STEM-nuanced teaching materials). Single interventions dominated (n = 21), primarily employing pedagogical models (e.g.,

PBL, DL). Combined interventions (n = 9) integrated models, approaches, strategies, technology, and contextual resources.

**Table 4**
*Distribution of Studies Based on The Type of Interventions*

| Category of intervention | Number of studies | Source |
|---|---|---|
| Pedagogical Models | 10 | Hafiz et al., 2020 |
| | | Kartini et al., 2021 |
| | | Nurmasari et al., 2024 |
| | | Salsabila et al., 2020 |
| | | Septiyana et al., 2019 |
| | | Shodiq & Rokhmawati, 2021 |
| | | Zaenuri et al., 2020 |
| | | Supriadi et al., 2023 |
| | | Rahmadani et al., 2022 |
| | | Djam'an et al., 2023 |
| Instructional Approach | 4 | Fauzana et al., 2019 |
| | | Apsari et al., 2023 |
| | | Susanti et al., 2023 |
| | | Rawani et al., 2024 |
| Teaching Strategies | 1 | Utari et al., 2019 |
| ICT-based Media | 2 | Gustiningsi et al., 2024 |
| | | Pradana et al., 2020 |
| Contextualized Worksheets | 4 | Jayanti et al., 2024 |
| | | Machromah et al., 2021 |
| | | Prastiti et al., 2020 |
| | | Susanta et al., 2023 |
| Combined Intervention | 9 | Dewi & Maulida., 2023 |
| | | Maslihah et al., 2021 |
| | | Maulana et al., 2019 |
| | | Pujiastuti & Haryadi., 2023 |
| | | Sari et al., 2022 |
| | | Wesna et al., 2021 |
| | | Yaniawati et al., 2023 |
| | | Domu et al., 2023 |
| | | Umbara & Nuraeni., 2019 |

For those studies utilized single interventions, 10 studies implemented a pedagogical model (e.g., PBL, DL, RMEng), 4 studies employed an instructional approach (e.g., RME, MEA), 4 studies developed contextualized students' worksheets (e.g., PISA-like problems), 2 studies utilized digital tools (e.g., VMK), and 1 study applied a unique teaching strategy (e.g., SBL strategy). In addition, there were 3 studies that integrated pedagogical models with digital tools (e.g., PBL with online flipped learning), 2 studies that combined models with complementary approaches (e.g., Reciprocal teaching-learning with RME), 1 study that merged a model with a strategy (e.g., Project-based blended learning with the cognitive conflict strategy), 1 study that paired an instructional approach with technology (e.g., RME with Adobe Flash Professional CS6), and 1 study that synthesized a model, digital media, and contextual materials (e.g., STEM-nuanced teaching material with ICT-assisted Preprospec Learning Model). Furthermore, the most used learning models are DL and PBL. The other learning models include STEM project-based learning model, Realistic Mathematics Engineering (RMEng) model, the generative learning model, thinking actively in a social context learning model, the cognitive neuroscience-based learning model, the model of creative thinking based on mathematical literacy. In addition, the RME approach is the most (6 studies) used intervention for enhancing students' mathematical literacy, whether used as a single or combined intervention. This review indicates the variety of a potential pedagogical intervention that can be used for enhancing students' mathematical literacy. It fits to the characteristics of mathematical literacy as a multidimensional construct that emphasizes the use of mathematical reasoning through diverse real-world contexts (OECD, 2023a).

The implementation of the pedagogical model offers an instructional framework that can facilitate a systematic and directed learning process to enhance students' mathematical literacy. This aligns with Belikuşaklı-Çardakidea's (2016) synthesis that underlines pedagogical models as a conceptual framework for teachers in designing learning processes, containing a description of teacher behaviour and a series of instructional activities for students to achieve specific learning objectives. An instructional approach refers to a structured and theory-driven framework employed by teachers to design, deliver, and facilitate learning experiences coherence with learning goals. The instructional approach is designed and employed by considering key aspects of philosophical concept, didactical theory, and method of teaching (Aflalo & Gabay, 2013; Rokaya, 2021). Therefore, conducting research about the implementation of an instructional approach can bridge the gap between the theory of mathematical literacy, didactical theory, empirical evidence of students' mathematical literacy, and teaching practice for enhancing students' mathematical literacy (Maass et al., 2019). Teaching strategy refers to teachers' way and approach to teaching to facilitate students' learning process. It enables teachers to drive the learning activity and create a learning environment that suits students' characteristics (Utari et al., 2019). In addition, it

reflects dynamics interaction of teachers, students, and the learning process in order to achieve learning objectives (Akdeniz, 2016a).

ICT-based learning media leverage technology to create interactive and visually rich learning environments. These tools help teachers to simplify the integration of complex concepts. The characteristics of ICT-based learning media enable students to construct geometrical objects, understand mathematical properties, develop conjectures, and enhance mathematical reasoning (Yildiz & Arpaci, 2024). In other words, increasing students' mathematical literacy can be facilitated by utilizing ICT as a learning media.

The contextualized worksheets and teaching materials utilize social context and personalized activities to facilitate students with a relevant learning process. Both students' worksheets and teaching materials are designed as students-centered learning interventions which provide structured activities for students, materials/content, and learning objectives (Akdeniz, 2016b). It enables students to learn and understand the mathematical concept from the real-world or cultural situations. Susanta et al. (2023) used ethnomathematics-based PISA-like problems to facilitate students with contextualized, personalized, and systematic learning process. It involves students in the problem-solving activity, stimulates critical and creative thinking, and enhances mathematical literacy. The effective development and implementation of teaching materials can facilitate the improvement of mathematics teaching and learning (Even, 2014). It also plays an essential role in engaging students with mathematical tasks (da Ponte et al., 2014).

Most of the studies reviewed used a single intervention. For example, they might employ an intervention like the PBL model (Hafiz et al., 2020; Zaenuri et al., 2020) and the RME approach (Apsari et al., 2023; Fauzana et al., 2020; Rawani et al., 2024). These studies provided in-depth analysis and very thorough evaluations of the characteristics and procedures of the interventions. Meanwhile, using a combination of interventions allows the tackling of multiple and often diverse obstacles that make learning hard. For example, Domu et al. (2023) put together the PBL model and online flipped learning. Their study tried to do two things simultaneously: get students to understand concepts in a way that also made them digitally fluent. The work incorporated technology into pedagogical intervention, which in line with the idea of TPACK (Mishra & Koehler, 2006). However, the study implies practical challenges that require teachers' expertise and resources availability (Donath et al., 2023; Wetzel et al., 2015).

### *Characteristics of the Interventions*

This systematic review identifies the majority of studies employing pedagogical models to enhance students' mathematical literacy. One of the main models identified was the PBL model. The PBL model provides collaborative problem-solving activities for students (Hafiz et al., 2020). This model facilitates students' learning through several phases, from the presentation of the initial problem to the evaluation of the

problem-solving process (Yew & Goh, 2016; Zaenuri et al., 2020). Along with PBL model, the DL model was also the most used model. The DL model involves the active construction of knowledge through active problem solving by students. Students not only work through the problems but also extensively discuss the content and process of what they are doing (Aldalur & Perez, 2023). This model guides students to understand the concept through several phases, namely problem stimulation, problem understanding, solving of the problem, verification of solution, and generalization (Tokada et al., 2017). Both PBL and DL align with Vygotsky's theory (1978), where students are structured to work in certain phases of a task and are given prompts to regulate their thinking.

This systematic review also found others pedagogical models which are used to enhance students' mathematical literacy. Kartini et al. (2021) implemented the STEM project-based learning model in their study. This model facilitates students with a project-based task, a collaborative activity, a contextual situation, and an interdiciplinary problem. These characteritics of the model foster students' procedural fluency, an adaptive reasoning, and problem solving skills. The Realistic Mathematics Enggineering (RMEng) model demonstrates a systematic learning process through the combination of realistic context, mathematical exploration, and engineering principles to build students' depth and applicative conceptual understanding (Nurmasari et al., 2024). The Thinking Actively in a Social Context (TASC) model was also identified in the study of Septiyana et al. (2019). This model provides structured stages of problem-solving to stimulate mathematical reasoning and decision making. The Generative learning model (Salsabila et al., 2020) offers active knowledge construction, metacognitive focus, and scaffolded inquiry, which contributes to students' conceptual understanding and retention. Shodiq & Rokhmawati (2021) used a cognitive neuroscience-based learning model to enhance students' mathematical literacy through several stages of contextual and reflective activities such as identification, plan, do, and see. The Model of Creative Thinking Based on Mathematical Literacy (Djam'an et al., 2023) demonstrates differentiated and collaborative problem-solving activities for enhancing students' conceptual clarity, procedural fluency, and critical thinking.

The implementation of pedagogical models helps teachers to demonstrates systematic syntax of learning for students. Different types and characteristics of pedagogical models have been identified, but they share a common goal of improving students' mathematical literacy. These pedagogical models offer a student-centered learning through a series of activities such as a contextual problem stimulation, a collaborative problem-solving, and an interpretation of solution. However, it leaves practical challenges to employ these models in terms of scalability and teachers' expertise.

The SBL strategy employed by Utari et al. (2019) has four stages: constructing mathematical context; posing mathematical cases; solving mathematical cases; and

applying mathematics. According to Isrok'atun & Tiurlina (2015), this SBL strategy makes students more actively involved in the learning process. They go on to say that the collaborative and interactive nature of SBL really promotes student engagement, and they seem to really enjoy participating. Moreover, the self-confidence that students experience when they solve SBL problems seems to be a true indicator of the success of SBL (Utari et al., 2019).

The most used instructional approach is Realistic Mathematics Education (RME). RME stresses contextual relevance and student-centered learning (Apsari et al., 2023; Fauzana et al., 2020). It employs real-world contexts and collaborative activities to enhance the learning experiences of the students (Freudenthal, 1991). Moreover, this approach pushes students to engage in both vertical and horizontal mathematization (Stacey & Turner, 2015). It enables students to improve their mathematical abilities (Öksüz et al., 2022; Putri et al., 2024; Turgut, 2021). The Model Eliciting Activities (MEA) was also identified as an instructional approach in this systematic review (Susanti et al., 2023). This approach is characterised by the use of a real-world problem as an initial learning stimulus (Parks, 2020). Moreover, the MEA approach offers students an iterative cycle of mathematical modelling activities (Deniz & Kurt, 2022). These MEA's characteristics can improve students' resilience and adaptive problem-solving skills.

Several studies used contextualized worksheets to facilitate students' learning process. The contextualized worksheets is characterized by the use of contextual problem and guide problem-solving activities (Jayanti et al., 2024; Machromah et al., 2021; Prastiti et al., 2020; Susanta et al., 2023). Another emergent style of teaching is that of using media that are part of Information and Communications Technology (ICT). Media like these can also serve as an innovative way to intervene in students' performance (Gustiningsi et al., 2024; Pradana et al., 2020). These types of interventions provide engaging and exploratory learning activities for students (Laksana, 2017; Maharjan et al., 2022; Widodo & Wahyudin, 2018). In addition, the characteristics of these interventions stimulate students' cognitive processes and mathematical literacy (Estacio et al., 2022).

The combination of different types of interventions was also identified in the previous studies. Maslihah et al. (2021) combined the RME approach with the PBL model. Meanwhile, Wesna et al. (2021) demonstrated the combination of the RME approach with a reciprocal teaching-learning model. Both studies used RME approach to facilitate the mathematization process with the students (Stacey & Turner, 2015). The RME combination with the PBL model lets students build and acquire knowledge by thinking and acting as problem solvers (Hafiz et al., 2020). More importantly, the RME-PBL combination facilitates students making active links between the mathematics and the contextual problems around them. The combination of RME approach with the reciprocal model allows students to actively involve themselves in the problem-solving activities (Wesna et al., 2021).

Sari et al. (2022) found the effectiveness of the combination of project-based learning model with a cognitive conflict strategy to enhance students' mathematical spatial literacy. The cognitive conflict strategy is characterised by the presentation of contradictory situations that stimulate students' interest and curiosity. This teaching method is based on the premise that students learn best when their prior knowledge is being challenged (Bedford et al., 2022; Sari et al., 2022). Investigating, designing, making decisions, and creating a product are a series of activities that the project-based learning model provides (Sari et al., 2022). The fusion of the project-based learning model with the cognitive conflict strategy nurtures students' comprehension of mathematical concepts, their procedural capabilities, and their reasoning in mathematics.

The integration of technology into the pedagogical interventions is also identified in this systematic review. Domu et al. (2023) integrated the Problem-Based Learning (PBL) model with the online flipped classroom. The PBL model leads students through organized problem-solving activities (Bosica et al., 2021; Rézio et al., 2022). Meanwhile, the online flipped classroom (OFC) offers flexibility of learning through its asynchronous and synchronous modes of learning (Jia et al., 2023). In addition, the flipped classroom emphasizes a collaborative and inquiry-oriented learning process (Fredriksen, 2021). The PBL-OFC combination stimulates students' desire for learning and problem-solving skills. Furthermore, this combination of interventions facilitates the inquiry process and enhances students' mathematical literacy. As well as Maulana et al. (2019) applied the Treffinger realistic model assistance Schoology where students can freely, independently, and actively build their way of thinking through the process of understanding and solving real problems around students. In addition, Yuniawati et al (2023) developed a mobile-based digital learning materials and integrated into blended learning model. Mobile-based digital learning materials allow students to enrich their knowledge through structured learning materials and activities with more flexible access. Meanwhile, the blended learning model provides a more personalized and student-centered learning experience so that students' knowledge construction process is by their needs, relevant to the context they experience, and supports problem-solving-oriented thinking processes (Ammar et al., 2024; Yaniawati et al., 2023).

Umbara and Nuraeni (2019) demonstrated the efficacy of integrating Adobe Flash Professional CS6 within the RME framework. The dynamic and interactive capabilities of Adobe Flash offer a visually engaging simulations of real-world mathematical scenarios. The tool aligns with RME's core principles of horizontal mathematization (Gravemeijer & Terwel, 2000) by enabling students to manipulate virtual objects and revisit the concept autonomously. The integration of Adobe Flash with RME demonstrates how technology amplifies contextual learning by making abstract concepts tangible. Similarly, Dewi and Maulida (2023) highlighted the individual merits of the combination of STEM-nuanced teaching materials and ICT-assisted Preprospec model. The combination synergizes STEM's contextual task, ICT-based media visualization,

and Preprospec's organizational syntax. It emphasizes interdisciplinary and authentic problem-solving through systematic phases of preparation, presentation, and reflection. In addition, the combination ensures systematic knowledge construction of students by simultaneously engaging in creative problem-solving and structured reflection. Therefore, the combination provides an effective learning environment for enhancing students' mathematical literacy.

***The Role of Teachers***

As instruction designers, teachers consider the cognitive, cultural, and contextual needs of students when designing the instructional interventions. In addition, teachers organize the interventions aligned with OECD's framework of mathematical literacy (2023a). When implementing a certain pedagogical intervention, such as the RME approach (Apsari et al., 2023; Fauzana et al., 2020), teachers designed contextual and meaningful activities by considering students' real-life experiences as a starting point for the learning scenario. The teacher's role as an instructional designer ensure that learning is well-planned, matches the needs of students, and meets the learning objectives. This role requires pedagogical content knowledge (PCK) to select tasks that promote mathematical literacy in terms of formulating (e.g., defining problems), employing (e.g., solving contextualized problems), and interpreting (e.g., contextualizing solutions) process. Teachers' instructional design expertise mediates between theoretical frameworks and practical application, facilitating the creation of a structured and assessable learning environment (Ozdilek & Robeck, 2009). Teachers' ability to design and contextualize content directly correlates with students' engagement and mathematical literacy development (Putri et al., 2024). The implementation of this role often implies practical challenges, especially regarding how teachers shift from traditional teaching to the adaptive and innovative instruction that suits the diverse characteristics of students (Lock & Scott, 2021).

Teachers also perform as facilitators which facilitates, guides, and encourages students to construct their knowledge through the exploration, discussion, and reflection of the learning process (Domu et al., 2023; Kartini et al., 2021). Teachers play their role as a facilitator by creating a learning environment for students to learn actively and independently (Maslihah et al., 2021). Furthermore, it stimulates the use of students' mathematical reasoning for constructing knowledge (Fredriksen, 2021; Maass et al., 2019). In other words, this teacher's role as facilitator enables the development of students' mathematical literacy (Haara et al., 2017). To be an effective facilitator, teachers have to be able to control their tendency and habit of dominating the learning process (Bolstad, 2023). It often requires self-control and years of experiences (Goos et al., 2014).

The dynamic of the learning process requires teachers to have adaptive ability in implementing interventions. As an adaptive implementer, teacher has to be able to

modify the intervention to address any potential challenges in the classroom (Parsons et al., 2018). For example, Dewi & Maulida (2023) developed STEM-nuanced teaching materials based on mathematical literacy indicators and relevance context, adjusting the implementation to the students' initial mathematical literacy and the dynamic of instructional classroom, while retaining core pedagogical principles of learning model. This role as adaptive implementers emphasizes the teachers' ability to serve a flexible and an innovative way of teaching to support students' needs (Gallagher et al., 2020; Parsons, 2012). However, it is not easy for teachers to balance the students' needs, curriculum objectives, and effective instruction (Bloom & VanSlyke-Briggs, 2019; Hill-Cloyd & Miller, 2023).

The role as formative assessor enables teachers to develop students' mathematical literacy by giving constructive feedback and continuous adjustment to the students' learning process. Previous studies used PISA-like problems as assessment tools for teachers to analyse students' initial mathematical literacy before adjusting the pedagogical interventions (Jayanti et al., 2024; Susanta et al., 2023). It indicates that teachers not only conduct a quantitative assessment but also critically analyse students' learning and a cognitive process (Dolin et al., 2018). Teachers' role as formative assessors emphasize that the assessment results are used to continuously improve the learning process (Bensley et al., 2016) and students' mathematical literacy (Coll et al., 2007).

Teachers serve as innovators, contributing to leading-edge practices in teaching, which are underpinned by the latest developmental research and design-based studies. The successful implementation of innovative teaching approaches depends on teachers' roles as agents of change and critical implementers (Maass et al., 2019). Yaniawati et al. (2023) involved teachers in the process of developing the mobile-based digital math learning materials that they then used in their study. Meanwhile, several studies that this review covers, investigate teachers implemented technology in their classrooms (Gustiningsi et al., 2024; Pradana et al., 2020; Umbara & Nuraeni, 2019). Since the inception of this systematic review, it has become clear that these studies – that is, the ones reported in this review – reflect not only the crucial role that teachers have when it comes to conceiving and applying innovative math learning approaches but also highlight the fact that teachers are the active creators of technology-based interventions (Mishra & Koehler, 2006). Furthermore, this role of teachers serves as the reason of effective mathematics instruction (Drijvers et al., 2019). Nonetheless, teachers have to confront practical challenges that are remarkable up to an effective balance between innovative practices and effective student learning (Wetzel et al., 2015).

In the Professional Learning Communities (PLCs), teachers are found to collaborate with their peers and experts to do the following: (1) design the interventions needed for professional development, (2) share best practices within the communities, and (3) engage in peer feedback that has the potential to change them in the way they need for the development of their professionalism. Shodiq and Rokhmawati (2021), as

researchers, collaborated with teachers to develop and redesign neuroscience-based activities through the lesson study cycles. Similarly, teachers collaborated with an expert to optimize digital tools for literacy development in implementing PBL model with online flipped learning (Domu et al., 2023). Teacher participation in PLCs represents an intentional strategy to organize professional development through collaborative efforts for enhancing instructional quality and improving students' mathematical literacy (Christensen & Jerrim, 2025). Collaborative design fosters pedagogical innovation and ensures fidelity in implementation (Voogt et al., 2015). In addition, teachers' professional development forms teachers' professional identity, which is critical for the quality of learning (Karaolis & Philippou, 2019). However, many challenges, such as time constraints limited resources, lack of institutional support, and evolving needs, often limit the sustainability of PLCs and professionals development (Mydin et al., 2024).

## Conclusion

This systematic review provides empirical evidence from 30 studies in Indonesia regarding pedagogical interventions for enhancing students' mathematical literacy. The findings offer critical insight in terms of the research trend, research objectives, types of interventions, teachers' role. Based on this systematic review, it is found an upward trend in the number of researches on this topic. Most studies used quantitative methods (50%) which reflects a preference for measurable outcomes. Most studies examined students' mathematical literacy on geometry and measurement content domain (33%) and the rest were distributed on others content domain. In addition, most studies were conducted on junior high school students (57%), and the rest were evenly distributed across all educational levels. This trend indicates the importance and relevance of the topic in Indonesia' s educational context. However, geographical bias persists, with 67% of studies conducted in Java Island, reflecting disparities in research infrastructure and funding and underscoring the need for policy interventions to support academic institutions in eastern Indonesia.

The reviewed studies demonstrated three primary research objectives such as: (1) evaluating the effectiveness of pedagogical interventions, (2) developing instructional materials/models, and (3) analysing post-intervention mathematical literacy. Most studies (67%) evaluated the effectiveness of pedagogical interventions on mathematical literacy by comparing post-intervention mathematical literacy with initial mathematical literacy or through a comparison study of experimental and control groups. In addition, 27% of studies focused on developing instructional models, materials, ICT-based media, and contextualized worksheets, while the small portion of the studies (6%) aimed to analyse students' mathematical literacy post-intervention, focusing on problem-solving processes aligned with OECD's framework.

This systematic review identifies six categories of pedagogical interventions. It utilized six primary types of interventions, such as pedagogical models (e.g., PBL, DL), instructional approaches (e.g., RME), teaching strategies (e.g., SBL), ICT-based media (e.g., VMK), contextualized worksheets (e.g., ethnomathematics-based PISA-like problems), and teaching materials (e.g., STEM-nuanced teaching materials). Single interventions were dominated (70%), which primarily employ pedagogical models. It offered in depth analysis and rigorous evaluation of the specific characteristics and procedures of the intervention. On the other hand, the used of combined interventions (30%) addressed multidimensional challenges of the learning process and enhanced mathematical literacy through interventions collaborations.

This systematic review identifies several pedagogical models that scaffold students' mathematical literacy. The PBL and DL models emerged as prominent pedagogical models used for enhancing students' mathematical literacy. The use of a teaching strategy is also identified in the form of SBL strategy. The characteristics of the SBL strategy facilitated students to develop their mathematical literacy. Meanwhile, the RME and the MEA are identified as effective instructional approaches to improve students' mathematical literacy. These instructional approaches used real-world problems as a starting point for students to develop conceptual understanding and enhance mathematical literacy. Moreover, the contextualized worksheet and ICT-based media were used in several previous studies which demonstrate structured, interactive, and relevant activities for enhancing students' mathematical literacy.

Six main roles of teachers in designing and implementing pedagogical interventions that contribute to the development of students' mathematical literacy were found. Teachers contribute as instructional designers, facilitators, adaptive implementers, formative assessors, innovators, and collaborators. These roles enable teachers to design, develop, implement, collaborate, and evaluate the effective pedagogical interventions for enhancing students' mathematical literacy. Although teachers often encounter various challenges to perform these roles successfully.

The results of the systematic literature review provide some important implications for future research directions. There is a need to expand the scope of research related to mathematical literacy to Eastern Indonesia, which has been less explored in academic studies. Research on the effect of pedagogical intervention towards affective aspects related to mathematical literacy should also be conducted in the future. Moreover, design research can be employed to produce a local instruction theory that combines aspects of ethnomathematics, technology, and pedagogical interventions for enhancing students' mathematical literacy.

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# Pedagoginės intervencijos, skirtos mokinių matematiniam raštingumui gerinti: sisteminė literatūros apžvalga

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## Santrauka

Ši sisteminė literatūros apžvalga analizuoja 30 empirinių tyrimų, kuriuose pristatomos pedagoginės intervencijos, skirtos Indonezijos mokinių matematiniam raštingumui gerinti. Sisteminėje apžvalgoje išskiriami keturi pagrindiniai aspektai: tyrimų tendencijos, tyrimų tikslai, pedagoginių intervencijų tipai ir ypatybės bei mokytojų vaidmenys. Duomenys buvo paimti iš Scopus, Science Direct, ERIC, AIP Publishing ir IOP Science duomenų bazių. Rezultatai rodo, kad tyrimų skaičius didėja, vyrauja kiekybiniai metodai, orientuoti į išmatuojamą poveikį. Dauguma intervencijų, ypač susietos su geometrijos ir matavimo temomis, buvo įgyvendintos vidurinėse mokyklose. Vis dėlto tyrimai tebėra geografiškai nevienodai pasiskirstę, net 67 proc. jų buvo atlikta Javoje. Apžvelgtuose tyrimuose buvo nustatyti trys pagrindiniai tyrimo tikslai: pedagoginių intervencijų veiksmingumo vertinimas, mokomosios medžiagos/modelių kūrimas ir matematinio raštingumo po intervencijos analizė. Ši sisteminė apžvalga atskleidžia šešis pagrindinius pedagoginių intervencijų tipus: pedagoginiai modeliai, mokymo metodai, mokymo strategijos, IKT grįstos mokymo priemonės, kontekstiniai pratybų sąsiuviniai ir mokymo medžiaga. Kiekviena intervencija turi unikalių savybių, kurios padeda ugdyti mokinių matematinį raštingumą. Be to, šioje sisteminėje apžvalgoje taip pat nagrinėjami šeši pagrindiniai mokytojų vaidmenys kuriant ir įgyvendinant pedagogines intervencijas, skirtas mokinių matematiniam raštingumui gerinti.

**Esminiai žodžiai:** *matematinis raštingumas, pedagoginės intervencijos, mokymo metodai, pedagoginis modelis, mokymo priemonės.*

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