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Mathematical Literacy of Prospective Teachers: A Systematic Review of Factors, Readiness, and Teacher Education Preparation

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Abstract: Mathematical literacy is a crucial competency for 21st-century teachers to foster critical thinking and problem-solving skills in various educational contexts. However, several pieces of evidence suggest that many prospective teachers struggle to develop mathematical literacy, which may hinder the effectiveness of mathematics learning. This study aims to provide a comprehensive overview of the mathematical literacy of prospective teachers through a systematic literature review of previous research. The study used the PRISMA protocol by searching articles from five reputable databases (ERIC, ProQuest, Taylor & Francis, Emerald Insight, and Scopus) using predefined inclusion and exclusion criteria. Of the initial search results of 8659 articles, only 13 articles were eligible for further review after the screening and duplication removal process. The analysis was focused on six research questions which included: (1) the geographical distribution of the research, (2) the academic background of the research subject, (3) the research topic, (4) factors that affect mathematical literacy, (5) the readiness of prospective teachers, and (6) the form of debriefing by the teacher education program. The results showed that the mathematical literacy of prospective teachers was influenced by both internal factors, such as conceptual comprehension, self-efficacy, and anxiety, as well as external factors, including pedagogical training and sociocultural contexts. However, most teacher education programs have not optimally emphasized the development of contextual and applicative mathematical literacy. This study highlights the importance of strengthening the teacher education curriculum through a contextual, activity-based, and culturally responsive approach, enabling prospective teachers to develop and effectively implement mathematical literacy in diverse learning contexts.

Keywords: mathematical literacy, prospective teacher, systematic review, teacher education, pedagogical preparation.

▪ INTRODUCTION

Mathematical literacy has become an important skill for being an active and informed citizen in a world where data, technology, and complex social demands are increasingly important. This global recognition is also reflected in international education policy frameworks, most notably the United Nations' Sustainable Development Goals (SDGs). Sustainable Development Goal 4 (SDG 4) aims to ensure inclusive and equitable quality education, promoting lifelong learning opportunities for all (Boeren, 2019). Within this framework, SDG Target 4.6 emphasizes the importance of functional literacy and numeracy among youth and adults as basic competencies in achieving other SDG targets (McKay, 2018). In this case, mathematical literacy is not only about acquiring basic computation skills but also about enabling individuals to interpret and evaluate data, solve authentic problems, and make reasoned decisions in personal, professional, and civic domains (Pillai, 2017). A person who has good mathematical literacy, thinks

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critically about information, assesses risks, understands public policy issues, and participates meaningfully in a democratic society. Therefore, improving mathematical literacy, especially for prospective teachers, is a strategic step to support the achievement of global education goals. This presents a challenge in various studies on how teacher education programs can enhance mathematical literacy, not only by mastery of teaching materials but also by the development of pedagogical skills and contextual understanding needed to teach mathematics in a way that is relevant to the real world (Boeren, 2019; McKay, 2018).

Concurrently, the OECD's Programme for International Student Assessment (PISA) identifies mathematical literacy as a key indicator for assessing students' ability to apply mathematics in real-life settings (OECD, 2023a). Mathematical literacy has been described as an essential element among the international basic competencies considered crucial in education (Platas & Sitabkhan, 2019; Rizki & Priatna, 2019). In this regard, mathematical literacy extends beyond computational fluency; it encompasses the ability to formulate, apply, and interpret mathematics in diverse and authentic situations (Genc & Erbas, 2019; OECD, 2023c). This multidimensional view of literacy includes engaging with mathematical problems situated in personal, societal, occupational, and scientific contexts, requiring individuals to reason, justify, and communicate solutions effectively. According to the PISA 2022 framework, mathematical literacy involves not only cognitive competencies but also metacognitive awareness, such as selecting appropriate strategies and evaluating the plausibility of results (OECD, 2023b). Such skills are particularly vital in a world inundated with quantitative information, from interpreting statistical reports in the media to making financial or health-related decisions. Thus, mathematical literacy is not a domain-specific competence but a transversal one, pivotal for lifelong learning and democratic participation.

The importance of improving mathematical literacy is also reflected by the increasing need for critical, creative, and adaptive thinking in solving daily problems (Maslihah et al., 2020; Singh et al., 2022). As nations strive to improve educational outcomes and global competitiveness of teachers, especially prospective teachers who are the central agents in fostering mathematical literacy among students (Dirgantoro, 2018; Wery & Thomson, 2013). Teachers' mastery of mathematical literacy has a significant impact on their students' learning experiences and achievement (Polk, 2006; Rizki & Priatna, 2019). However, much evidencesuggests that many prospective teachers struggle with key aspects of mathematical literacy, including contextual understanding, problem-solving, and mathematical communication (Beswick et al., 2011; Yustitia et al., 2020).

From a theoretical perspective, this study adopts the PISA 2022 framework, which defines mathematical literacy as "an individual's capacity to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts" (OECD, 2023c, p. 28). This framework integrates three mathematical processes (formulating, employing, and interpreting) which intersect with content (e.g., quantity, space, change) and context (e.g., personal, societal, occupational). It also emphasizes the importance of cognitive demands such as problem-solving and reasoning, and this model has proven influential in both research and curriculum development globally (Genc & Erbas, 2019; Kramarski & Mizrachi, 2004).

Although mathematical literacy has received increasing attention, differing views persist in the literature regarding the most effective way to develop it in teacher education.

Some researchers recommend instilling literacy early through foundational courses and mathematical modeling (Haara et al., 2017; Aydoğan Yenmez & Gökçe, 2023; Nurmasari et al., 2023), the use of ICT in developing numeracy (Genlott & Grönlund, 2016; Hu et al., 2018), or mathematical interventions in informal learning settings (Carter et al., 2024). Other studies emphasize practice-based learning through learning design and culturally relevant activities (Astambayeva et al., 2021; Kurniawan et al., 2024). Additionally, some research highlights the affective factors, such as anxiety and low confidence, which hinder prospective teachers' ability to engage with mathematical content meaningfully (Bursal & Paznokas, 2006; Ören Vural & Sevgi, 2024). While these studies are valuable, they have not addressed the specific roles and needs of prospective teachers. Prospective teachers need not only to possess mathematical literacy but also to be able to develop and transfer it to diverse students. Unfortunately, many teacher education programs still struggle in integrating mathematical literacy in a meaningful and contextual way (Bansilal et al., 2015; Muñiz-Rodríguez et al., 2016).

In Indonesia, the low mathematical literacy scores in PISA (OECD, 2023a) have led to national efforts, such as the Asesmen Kompetensi Minimum (AKM) initiative, which aims to embed literacy in school assessments (Kemendikbud, 2022). However, research indicates that Indonesian prospective teachers face difficulties in understanding and applying mathematics in real-life contexts (Rahmawati et al., 2023; Yustitia et al., 2020). This underscores the urgency for teacher education reform, not only in Indonesia but globally.

To fill this gap, this study conducts a systematic literature review focused exclusively on mathematical literacy among prospective teachers, with attention to geographical trends, program structures, contributing factors, and educational strategies. This SLR is distinct in its scope, offering both a synthesis of existing knowledge and a foundation for improving policy and practice in teacher education. The following predetermined research questions (RQs) have definite answers from this thorough scientific review:

1. What is the geographical distribution of research sites? (*To identify regional patterns, gaps, and global equity in research, focus on prospective teachers.*)
2. What study programs do the research subjects belong to? (*To understand whether mathematical literacy is being studied across different teacher education pathways (e.g., primary vs. secondary).*)
3. What research topics are related to the mathematical literacy of prospective teachers? (*To map current scholarly focus and discover underexplored themes or trends in the field.*)
4. What are the factors that affect the mathematical literacy of prospective teachers? (*To identify both internal (e.g., self-efficacy) and external (e.g., pedagogy, context) factors that influence teacher development.*)
5. How is the readiness of prospective teachers in helping to improve students' mathematical literacy? (*To assess perceived and actual readiness for teaching mathematics in a literacy-oriented way.*)
6. How does teacher education prepare prospective teachers for mathematical literacy? (*To evaluate which methods and strategies are most effective and identify areas for improvement.*)

By answering these questions, this review aims to provide a comprehensive and critical synthesis of existing studies, while offering insights that can inform curriculum design, teacher preparation, and future research directions.

▪ METHOD

This study uses the Systematic Literature Review (SLR) approach to ensure a systematic, comprehensive, and transparent review of the existing literature on mathematical literacy in prospective teachers. The SLR design enables the identification of patterns, gaps, and emerging themes from a wide array of sources. The study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure transparency and compliance with international standards. PRISMA employs a systematic review process consisting of four stages: identification, screening, feasibility assessment, and inclusion (Moher et al., 2009). Domain knowledge as a researcher in the field of mathematics education with spesific expertise in mathematical literacy and teacher prepparation was applied to refine the screening process, interpret findings, and ensure relevance to educational contexts.

Research Design

This study employed a qualitative SLR design to systematically explore and synthesize peer-reviewed literature addressing mathematical literacy among prospective teachers. The review process was guided by four stages: identification, screening, eligibility assessment, and inclusion, using the PRISMA model as illustrated in Figure 1. The objective was to identify research trends, influential factors, and pedagogical strategies relevant to the development of mathematical literacy in teacher education.

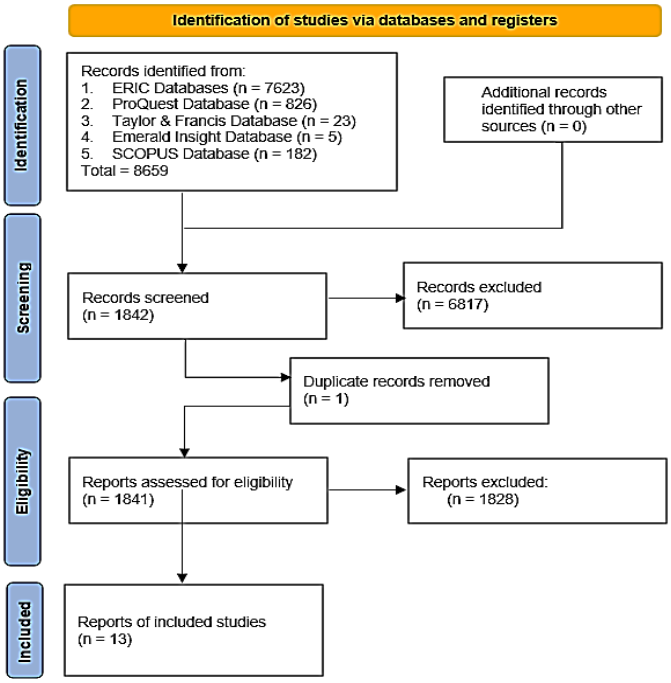

Figure 1. PRISMA flowchart

Search Strategy

The article search was conducted across five major academic databases relevant to education and the social sciences, namely ERIC, ProQuest, Taylor & Francis, Emerald Insight, and Scopus. These databases were selected due to their extensive indexing of peer-reviewed literature in the field of educational research, including mathematics education and teacher training. The search process was carried out in November 2024 and followed a systematic and replicable protocol to ensure comprehensive coverage.

An expanded Boolean search string that included synonyms and related terms for both mathematical literacy and the target population was employed to avoid potential selection bias stemming from overly narrow terminology. The search keywords used were: ("mathematical literacy" OR "mathematics literacy" OR "quantitative literacy" OR "numeracy") AND ("prospective teacher" OR "preservice teacher" OR "student teacher" OR "teacher candidate") AND ("teacher education" OR "initial teacher training" OR "teacher preparation"). This expanded query was intended to capture diverse formulations and descriptors used in different educational and regional contexts, ensuring that potentially relevant studies were not excluded due to terminological variation. Boolean operators (AND, OR) were used strategically to maximize the inclusivity of the search results without compromising relevance.

The database search using this refined query yielded a total of 8,659 articles, distributed as follows: (1) ERIC: 7,623 articles, (2) ProQuest: 826 articles, (3) Taylor & Francis: 23 articles, (4) Emerald Insight: 5 articles, and (5) Scopus: 182 articles. The entire review process, including the stages of identification, screening, eligibility, and inclusion, is illustrated in Figure 1 using the PRISMA flow diagram. This structured and transparent procedure supports the reproducibility and credibility of the review findings.

Inclusion and Exclusion Criteria

Screening Stage

Screening criteria were carefully designed to refine the initial search result set to a collection of studies that were methodologically sound, topically relevant, and timely. The goal of this stage was to ensure that only articles meeting a predetermined set of scholarly standards were included in subsequent analyses.

Specifically, the screening aimed to: (1) ensure temporal relevance by limiting the corpus to studies published between January 2015 and October 2024, thus reflecting current practices and educational discourse on mathematical literacy and teacher preparation; (2) maintain academic rigor by including only peer-reviewed, empirical journal articles, thereby ensuring that the selected studies have undergone critical scholarly evaluation and presented original data; (3) guarantee linguistic accessibility by restricting the review to English-language publications, enabling consistent interpretation and minimizing translation-related biases; (4) ensure access and usability by including only full-text articles, whether open-access or accessible via institutional subscriptions, to facilitate in-depth appraisal; (5) maximize topical relevance by focusing on studies that explicitly addressed mathematical literacy about prospective, preservice, or student teachers; and (6) limit disciplinary scope to the field of mathematics education or teacher education, to maintain conceptual coherence with the research objectives.

These multilayered filters contributed to enhancing the objectivity and reproducibility of the review process. The complete inclusion and exclusion criteria applied during the screening stage are summarized in Table 1.

Table 1. Criteria of inclusion and exclusion in the screening stage

Criteria	Inclusion	Exclusion
Year of publication	Articles published between January 2015 and October 2024 to capture recent developments	Articles published before 2015 or after October 2024
Type of publication	Peer-reviewed empirical studies articles, including qualitative, quantitative, or mixed-methods	Non-empirical works (e.g., conceptual papers, editorials), proceedings, or book chapters
Language	Articles written in English for consistency in interpretation	Articles in languages other than English
Access	Full-text available (open access or through institutional access)	Abstract-only articles or articles behind paywalls without institutional access
Topical relevance	Focus on mathematical literacy in the context of prospective teachers or teacher education.	Irrelevant focus; articles that mention keywords without substantive engagement
Field of study	Situated within the field of mathematics education or teacher education	Conducted in non-educational disciplines (e.g., engineering, economics, general pedagogy)

Eligibility Stage

Following the initial screening process, a total of 1,842 articles remained for further eligibility assessment after removing two duplicate entries. This stage involved a more rigorous evaluation of the articles' content and relevance to ensure alignment with the research objectives and to reduce selection bias that may have occurred due to the use of broad search terms.

The eligibility assessment involved four primary criteria: the relevance of the title and keywords, alignment of the research focus, disciplinary fit, and full-text availability. Articles were excluded at this stage based on a more detailed reading of abstracts and, when necessary, complete texts. Specifically, 1,738 articles were excluded because they were tangential or unrelated to mathematical literacy in prospective teachers, despite matching some of the search terms. These typically included studies that mentioned mathematical literacy but focused on students in general, early childhood education, or digital literacy unrelated to mathematical content. An additional 74 articles were excluded because they lacked empirical grounding, were too generic, or fell outside the discipline of mathematics education, such as studies in pure mathematics, engineering, or education technology without a pedagogical application. Table 2 outlines the inclusion and exclusion criteria for articles at the eligibility stage.

Table 2. Criteria of inclusion and exclusion in the eligibility stage

Criteria	Inclusion	Exclusion
Article title & keyword	Reflect the study's focus on mathematical literacy and prospective teachers.	Use of keywords without substantive focus, an ambiguous or misleading title, and an abstract
Content relevance	Addresses at least one of the research questions or discusses empirical findings related to ML.	Lacks focus on teacher education, or mathematical literacy, which is not central to the study
Disciplinary	Situated in mathematics	Belongs to unrelated fields (e.g.,

focus	education or teacher education	statistics, engineering, general pedagogy without a math context)
Accessibility	Fully accessible (either open access or institutional access)	Only abstracts are available or inaccessible due to paywalls
Research design	Presents empirical findings with a transparent methodology	Theoretical, opinion-based, or lacking methodological description

To ensure methodological rigor and minimize the risk of bias in the review, the 13 articles that met the eligibility criteria were further subjected to a manual quality appraisal. Although no specific software tools such as MMAT or CASP were applied digitally, the core principles from these frameworks were adopted in evaluating the studies. Each article was examined based on the clarity of its research objectives, the suitability of its design and methods, the transparency of data collection and analysis, the relevance to the review focus, and the presence of reflections on limitations or ethical considerations. Articles that met most of these criteria were retained in the final synthesis. While some studies did not explicitly mention ethical procedures or had limited discussion of study limitations, they were nevertheless included due to the robustness of their design and strong relevance to the research questions. This internal quality screening ensured that only credible, peer-reviewed, and thematically aligned research was incorporated into the final analysis. Through this careful and transparent eligibility process, the final selection consisted of 13 empirical journal articles that offer meaningful insights into the landscape of mathematical literacy in prospective teacher education, forming the basis for the next stage: data analysis and synthesis.

Data Analysis

This review analyzed thirteen selected studies using a thematic analysis approach, based on the six steps introduced by Braun & Clarke (2006). The process begins with repeated readings to understand the content and identify initial insights, followed by manual coding of relevant concepts, keywords, and patterns. These initial codes were grouped into potential themes, which are then reviewed and refined to ensure clarity and consistency. Refined themes were then defined and named to represent the main ideas in the data, before being organized into a narrative of the findings that integrates with the study's objectives.

The entire process was conducted manually, without the aid of software such as NVivo. A structured data extraction form was used to ensure consistency, including metadata, study characteristics, and relevance to the research questions. The resulting themes were mapped to six primary research questions and classified into internal factors (such as self-efficacy, cognitive abilities, and affective dispositions) and external factors (such as curriculum, institutional policies, and pedagogical strategies). This approach helped systematically organize the findings and reveal patterns across educational contexts and regions. Details of each study and its characteristics are presented in Table 3, which forms the basis for the synthesis in the results section.

Table 3. List of reviewed articles

No	Author	Year	Title	Country	Research Design	Participants	Instruments Used	Key Findings
1	Güler & Arslan	2017	Mathematical Competencies Required by	Turkey	Qualitative	63 prospective high school mathematics	5 written PISA-style tasks	Many participants struggled to distinguish between “competency” and

No	Author	Year	Title	Country	Research Design	Participants	Instruments Used	Key Findings
			Mathematical Literacy Problems			teachers		"process." There is limited awareness among prospective teachers about the competencies required by mathematical literacy tasks.
2	Lestari et al.	2018	Gender differences in prospective teachers' mathematical literacy: problem solving in the occupational context of a shipping company	Indonesia	Mixed-method	157 prospective teachers	Mathematical literacy test	Female students performed better in mathematical literacy than their male counterparts. Females exhibited stronger reasoning and interpretation skills.
3	Suharta & Suarjana	2018	A Case Study on Mathematical Literacy of Prospective Elementary School Teachers	Indonesia	Qualitative (Case Study)	12 prospective elementary school teachers	Test and interview guide	Mathematical literacy levels were generally low. Females and students with strong mathematical skills performed better. Content strength varied: strongest in statistics/probability, weakest in algebra/functions.
4	Ilhan et al.	2019	What is the predictive power of visual mathematics literacy perception and its sub-dimensions for geometry success?	Turkey	Quantitative (correlational study)	232 prospective teachers	Visual Mathematics Literacy Perception Scale, Geometry Test	There is a positive correlation between visual mathematics literacy perception and success in geometry. Visual literacy is a significant predictor of performance in geometry.
5	Aydın & Özgeldi	2019	The PISA Tasks: Unveiling Prospective Elementary Mathematics Teachers' Difficulties with Contextual, Conceptual, and Procedural Knowledge	Turkey	Mixed methods	52 prospective elementary mathematics teachers (12 interviewed)	26-item PISA test + interviews	Significant difficulties were found in contextual and conceptual knowledge. Procedural understanding was better, but many struggled to explain their reasoning mathematically.
6	Ozgen	2019	Problem-Posing Skills for Mathematical Literacy: The Sample of Teachers and Preservice Teachers	Turkey	Qualitative case study	13 preservice and five in-service mathematics teachers	3 open-ended ML problem-posing tasks	Most posed problems were open-ended and fell under occupational/personal contexts. Teachers outperformed preservice teachers in posing mathematically rich problems.
7	Hall & Zmood	2019	Australia's literacy and numeracy test for initial teacher education students: Trends in numeracy for low- and high-achieving students	Australia	Descriptive analysis	20 teacher education students (top 10 and bottom 10 scorers on LANTITE numeracy)	LANTITE numeracy test data	High-achieving students displayed stronger skills in interpreting and applying mathematical information. The study recommends enhanced institutional support for low achievers to develop numeracy competency.
8	Canbazoğlu & Tarim	2020	An activity-based practice for improving mathematical literacy and awareness of elementary school teacher candidates	Not mentioned	Mixed-methods (embedded design)	73 preservice elementary teachers	Achievement test, awareness test, reflective interviews, teaching activities	Activity-based teaching significantly improved mathematical literacy and awareness, with cooperative learning enhancing problem-solving and reflective thinking skills.

No	Author	Year	Title	Country	Research Design	Participants	Instruments Used	Key Findings
9	Astambayeva et al.	2021	Algorithmic methodological and mathematical literacy of the future primary education teacher: Perspective of learning technology	Kazakhstan & Russia	Experimental study	86 preservice primary teachers (42 control, 44 experimental) + 38 in-service teachers	Diagnostic tests (Bloom's taxonomy), questionnaires, and interviews	A special course on teaching algorithms significantly improved the algorithmic, methodological, and mathematical literacy of preservice teachers; the achievement of the experimental group increased from 25% to 73%.
10	Aydoğan Yenmez & Gökçe	2023	Investigating the Role of Modeling Practices on Mathematical Literacy	Not mentioned	Mixed methods (thoroughly mixed concurrent equal status)	113 preservice mathematics teachers	Computer-based PISA test (21 items), semi-structured interview	Mathematical modeling practices significantly improved participants' contextual and conceptual understanding; however, they struggled to connect mathematics to real-life contexts.
11	Rahmawati et al.	2023	Profile of Mathematical Literacy of Prospective Teacher Students in Solving Integral Calculus Problems Seen from Learning Independence	Indonesia	Qualitative descriptive	28 students (initial participants); 6 students (analyzed in-depth: 2 high, 2 moderate, 2 low learning independence)	Mathematical literacy test (integral calculus problems), Learning Independence Questionnaire, and interviews.	Students with high learning independence demonstrated proficiency in all seven indicators of mathematical literacy. Those with moderate independence achieved most indicators but had difficulties in using symbolic operations. Students with low independence may struggle to model problems mathematically or interpret data accurately, which can lead to incorrect solutions.
12	Kurniawan et al.	2024	Integrating cultural artifacts and traditions from remote regions into developing mathematics lesson plans to enhance mathematical literacy	Indonesia	Qualitative ethnographic study	Preservice teachers, mentor teachers, and 2 local cultural leaders	Observations, interviews, and cultural artifact analysis	Integrating local cultural artifacts into lesson planning enhanced students' mathematical literacy, particularly in geometry, and promoted culturally relevant and meaningful learning experiences.
13	Ören Vural & Sevgi	2024	An Investigation of Mathematics Education Studies Conducted with Turkish Primary Teachers	Turkey	Systematic review	– (100 studies analyzed)	Publishing Classification Form	Most studies have focused on perceptions, attitudes, and pedagogical content knowledge, using mainly quantitative methods with small sample sizes. Geometry was the most studied topic among the learning areas.

▪ RESULT AND DISSCUSSION

The findings of the 13 selected articles will be presented explicitly based on the topic derived from the research question. The findings will be carefully analyzed and synthesized to provide a comprehensive overview of this research.

QR1. Geographical Distribution of Research Sites

Research on mathematical literacy among prospective teachers was conducted in various locations, covering several countries with diverse geographical backgrounds. Of the 13 articles from a systematic review of the PRISMA process, eleven articles came from four countries, while the other two did not include country names. Of the four

countries, Turkey dominates the distribution of research sites with a percentage of 45% (Aydın & Özgeldi, 2019; Güler & Arslan, 2019; Ilhan et al., 2019; Ören Vural & Sevgi, 2024; Ozgen, 2019), followed by Indonesia with a percentage of 36% (Kurniawan et al., 2024; Lestari et al., 2018; Rahmawati et al., 2023; Suharta & Suarjana, 2018), and 9% each from Australia (Hall & Zmood, 2019) and Kazakhstan (Astambayeva et al., 2021). This pattern may reflect a regional research focus driven by systemic needs to improve mathematical literacy. For example, both Turkey and Indonesia have launched national initiatives that emphasize mathematical competencies in their school curricula (e.g., Turkey's integration of mathematical literacy and Indonesia's Minimum Competency Assessment, implemented since 2020). These policies may have stimulated empirical studies in teacher education to support improvements in student achievement. A recent review of mathematical literacy research also reveals a notable contribution from Turkey and Indonesia, underscoring this regional concentration (Kappassova et al., 2025). The distribution of countries is shown in Figure 2.

Figure 2. Article distribution by research site country

An interesting comparison among these four countries is related to their participation and positioning in the PISA. Turkey is a PISA member and has varied performance in mathematics. According to the 2018 PISA Results, Turkey was ranked 39th out of 81 nations in terms of mathematical literacy (OECD, 2023a). Thus, Turkey has an opportunity to increase mathematical literacy outcomes among students and prospective teachers. Indonesia has a relatively lower PISA assessment score compared to Turkey. Based on the results of PISA 2022, Indonesia ranks 70th out of 81 countries in terms of mathematical literacy (OECD, 2023a). Research in Indonesia often emphasizes the importance of contextualizing mathematics learning within local cultural contexts to develop mathematical literacy skills, in addition to enhancing student performance at the international level. In PISA 2022, Kazakhstan ranks 46th out of 81 in the math literacy ranking (OECD, 2023a). It means the country is positioned in the middle and actively finds solutions to improve mathematical literacy through much research among prospective teachers. Australia, one of the participants in this study, has the

highest PISA rating among Turkey, Indonesia, and Kazakhstan. In the 2022 PISA test, Australia ranked 17th out of 81 countries in terms of mathematics literacy (OECD, 2023a). It means that the mathematical performance of Australian students is above average; however, the mathematical literacy of prospective teachers requires more research to improve and maintain a higher international ranking.

Some studies do not explicitly identify the research locations, indicating the need for more equitable global representation. The focus on teacher education in some countries also reflects strategic reform agendas and the drive to improve international rankings, which drives research in this area. However, it is important to remember that similar interventions can have varying impacts across countries due to social, economic, and cultural differences. Factors such as classroom norms, levels of teacher autonomy, and access to digital technology can influence the implementation and acceptance of mathematical literacy programs (Chan et al., 2021; Jurdak, 2018). Therefore, cross-national research should seriously consider contextual factors when evaluating the effectiveness and replicability of a learning model.

QR2. Subjects' Academic Background

The research subjects are primarily prospective teachers enrolled in the teacher training program. Of the 13 articles, the research subjects of 7 articles (54%) were mathematics education students (Aydoğan Yenmez & Gökçe, 2023; Güler & Arslan, 2019; Ilhan et al., 2019; Kurniawan et al., 2024; Lestari et al., 2018; Ozgen, 2019; Rahmawati et al., 2023), five articles (38%) were primary education students (Astambayeva et al., 2021; Aydın & Özgeldi, 2019; Canbazoğlu & Tarim, 2020; Kızıltepe et al., 2020; Suharta & Suarjana, 2018), and 1 article (8%) was both mathematics and primary education students (Hall & Zmood, 2019). This means that the studies carried out not only focus on prospective teachers from the mathematics education study program but also from the elementary education study program. This is particularly relevant, considering that primary education teachers play a crucial role in laying the foundation for students' mathematical literacy in the early stages of learning (Yustitia et al., 2020).

However, despite the involvement of prospective primary education teachers, the study remains limited in scope because its focus has yet to expand to other subject teachers, such as science, social studies, or economics teachers. Expanding the focus beyond mathematics and primary education teachers is crucial, as mathematical literacy is relevant across disciplines. PISA emphasizes that mathematical literacy encompasses the ability to understand and apply mathematics in real-life contexts (OECD, 2023c). Mathematical literacy is a cross-disciplinary ability that must be taught not only by mathematics or basic education teachers but also by teachers of other subjects (Bolstad, 2020), such as computer science, physics, geography, or biology that inherently use mathematical concepts in their learning (Kuznetsova et al., 2023). Therefore, strengthening mathematical literacy among prospective teachers from diverse academic backgrounds ensures students receive a well-rounded education, fostering problem-solving and analytical thinking across multiple disciplines.

These limitations highlight the need for more comprehensive research on mathematical literacy to ensure that prospective teachers from diverse backgrounds have adequate competence. By integrating mathematical literacy across various discourses,

students can develop these skills in broader dimensions, helping them understand everyday phenomena and prepare for potential challenges.

QR3. Topics in Mathematical Literacy

Based on the 13 articles analyzed, they could be grouped into two big topics associated with mathematical literacy research topics for prospective teachers: (1) mathematical literacy competencies and challenges in teaching; (2) mathematical literacy in social, cultural, and learning contexts.

The first topic, competencies in mathematical literacy and related challenges in pedagogy, combines prospective teachers' mathematical literacy skills with the challenges they face in developing these competencies. Several studies on the competencies and factors influencing mathematical literacy among prospective teachers highlight various crucial dimensions of mathematical skills. For example, Ilhan et al. (2019) investigate knowledge of visual mathematical literacy and its correlation to students' performance in geometry, while also examining how this type of literacy can be used to predict performance in that area. Furthermore, the study by Aydın & Özgeldi (2019) on the knowledge needed to solve PISA-related problems and the difficulties faced by prospective teachers related to contextual, conceptual, and procedural knowledge. Subsequent research by Güler & Arslan (2019) further elaborated on prospective teachers' awareness of critical competencies in answering PISA-related items and distinguishing between mathematical processes and skills required for solving them. Another important question is the development of algorithmic, methodological, and mathematical literacy, which is necessary in successful didactics (Astambayeva et al., 2021). Conversely, Ören Vural & Sevgi (2024) and Canbazoğlu & Tarim (2020) investigate the influence of mathematical anxiety on prospective teachers' performance, emphasizing the importance of improving pedagogical content knowledge and effective teaching methods to enhance their mathematical literacy.

The second topic examines how social, cultural, and educational contexts influence mathematical literacy. Therefore, research was conducted by integrating culture and social context into mathematics learning. For instance, Kurniawan et al. (2024) demonstrate how local cultural artifacts and traditions become integral to mathematics learning by a process of mathematization that is contextually relevant to the local culture. This enhances mathematics learning by connecting mathematical concepts with regional culture. Ozgen (2019) provides information about mathematical literacy, elaborating on the meaning and component structure. This suggests that it plays an essential role in a person's development and interacts with other forms of literacy embodied in the curricula within the classrooms. This shows the importance of improving mathematical literacy beyond classroom walls. On the contrary, Hall & Zmood (2019) refer to concerns about linguistic complexity embedded in mathematical literacy tasks and the effects of socioeconomic status on individuals' numeracy and mathematical understanding. This is another critical reason that more inclusive and interpretable problem formulations should be devised. Lastly, Lestari et al. (2018) and Suharta & Suarjana (2018) examine the influences of gender differences on prospective teachers' communicative competencies and mathematical reasoning two significant issues in education concerning equity and inclusion toward mathematical literacy for all.

In summary, these studies show that the mathematical literacy of prospective teachers cannot be captured by just one dimension or view; instead, it is a complex construct containing many elements that need to be formed, such as deep knowledge of mathematics and skill in teaching mathematics effectively, about social, cultural, and everyday situations. As such, the preparation of prospective teachers should emphasize the interaction between technical, pedagogical, and sociocultural contexts to develop influential and meaningful teaching practices. Prospective teachers should possess more than just a superficial knowledge of mathematics; they should gain a deep understanding of the subject area to become proficient in presenting and representing ideas, participating in problem-solving activities, and applying mathematical thinking (Gearhart, 2007). A deep understanding of mathematical concepts should enable teachers to relate these theories to real-life problems encountered in everyday life (Afifah et al., 2018). Prospective teachers must develop a deep understanding of theoretical models, enabling flexible application of concepts in various contexts (Fenwick et al., 2013). Educators should be able to communicate their understanding of abstract theories to students clearly and in a relatable manner, thus making the information clear and relevant to real-life situations (Lojo, 2011; Ratinen et al., 2015).

QR4. Factors Influencing Mathematical Literacy

The factors that influence the mathematical literacy of prospective teachers could be categorized into internal and external components. The internal factors include different aspects that pertain to individual ability and individual characteristic, such as (1) perception of visual mathematical literacy (Ilhan et al., 2019); (2) self-efficacy or self-confidence (Ilhan et al., 2019); (3) mastery of different types of knowledge, whether conceptual, procedural, and contextual knowledge (Aydın & Özgeldi, 2019); (4) the ability in applying knowledge in solving mathematical problems (Aydın & Özgeldi, 2019); (5) the ability in representing mathematical ideas in various forms, such as symbols, images, or language (Rahmawati et al., 2023); (6) problem-solving skill (Rahmawati et al., 2023); (7) critical thinking skill (Rahmawati et al., 2023); (8) mathematical communication (Rahmawati et al., 2023); (9) mathematical anxiety (Lestari et al., 2018; Ören Vural & Sevgi, 2024); (10) confidence in teaching (Ören Vural & Sevgi, 2024; Ozgen, 2019); and (11) belief in problem-solving (Ozgen, 2019). Internal factors, such as perception, self-confidence, and expertise in all dimensions of mathematical knowledge (conceptual, procedural, and contextual), suggest that mathematical literacy is closely related to an individual's ability to understand and apply mathematics broadly. For example, high self-efficacy may encourage prospective teachers to participate more actively in mathematics learning. On the other hand, some aspects, such as the ability to explain mathematical concepts and communicate effectively in mathematics, reveal that mathematical literacy encompasses dimensions of interpersonal skills, empowering prospective teachers to share knowledge effectively with their learners. Fear of mathematics remains a significant factor that warrants attention when designing teacher education programs. Thus, developing these internal factors requires an integrated approach that strengthens confidence and incorporates relevant problem-based learning.

On the other hand, external factors affecting mathematical literacy in prospective teachers relate more to conditions outside the individual, which may influence their learning and teaching practice. These external factors are: (1) the use of teaching

materials, technology, or other relevant resources (Ilhan et al., 2019); (2) pedagogical training and exercises (Astambayeva et al., 2021); (3) the integration of local culture in mathematics learning (Kurniawan et al., 2024); (4) the academic background of prospective teachers regarding academic achievement and admission through national selection (Suharta & Suarjana, 2018); (5) availability of adequate technology and educational resources (Hall & Zmood, 2019); (6) the quality of pedagogical training that involves practical experience and the application of real problems through the curriculum (Astambayeva et al., 2021); (7) exposure to problem-solving methodologies applied in the pedagogical training of prospective teachers (Canbazoğlu & Tarim, 2020); (8) socioeconomic status, which may affect the access of prospective teachers to relevant educational resources (Hall & Zmood, 2019); (9) the context in which mathematical knowledge is applied, such as in personal life, at work, or in society(Aydoğan Yenmez & Gökçe, 2023; Suharta & Suarjana, 2018); and (10) designing activities that focus on the development of mathematical literacy (Canbazoğlu & Tarim, 2020). These external factors, such as the quality of pedagogical training and access to technology, become important in supporting prospective teachers' mathematical literacy. Systematically designed and practice-oriented training, when combined with appropriate educational technology, can expand prospective teachers' abilities to apply mathematical concepts in various authentic learning contexts. Furthermore, integrating local cultural elements into mathematics learning can make mathematics more relevant and enrich their mathematical literacy. Other factors, such as prospective teachers' socioeconomic status and educational background, also underscore the importance of policies that ensure equal access to educational resources. Therefore, improving mathematical literacy requires a holistic approach that focuses on enhancing personal competencies and creating a conducive learning environment through inclusive education policies, high-quality training, and engaging learning experiences.

It is also important to consider the interaction between internal and external factors, as they are not isolated. High-quality external factors, such as access to practical pedagogical practice and adequate technological resources, have positively influenced internal factors such as self-efficacy, confidence, and motivation in mathematics teaching (self-efficacy in teaching mathematics is linked to pedagogical practice) (Berg et al., 2025). Research on technology integration also indicates that increased knowledge of technology enhances self-efficacy and promotes the use of technology in teaching mathematics, creating a reinforcing cycle between external resources and internal capabilities (David et al., 2023). Likewise, strong internal dispositions, such as high self-confidence and a strong belief in problem-solving abilities, enable prospective teachers to utilize external learning opportunities more effectively. This synergistic interaction suggests that the development of sustainable mathematical literacy requires an integrative strategy that simultaneously develops individual capacity and provides a supportive learning environment. Such an approach not only strengthens prospective teachers' pedagogical readiness but also enhances their resilience in facing the complex and contextual challenges of teaching mathematics.

QR5. Prospective Teachers' Readiness

The readiness of prospective teachers to promote students' mathematical literacy varies significantly, depending on factors such as individual mathematical knowledge,

training experiences, and confidence in their mathematics skills. A review of the 13 articles reveals that while some prospective teachers appear well-prepared, others require additional preparation.

Some prospective teachers think they are ready because they have relevant skills and knowledge that boost their confidence. Some research studies show that understanding mathematics visual literacy helps better prepare students for improving mathematics literacy (Ilhan et al., 2019). Prospective teachers with a high level of mathematical literacy and independence in learning are better prepared to involve students in mathematical reasoning and problem-solving activities (Rahmawati et al., 2023). Moreover, prospective female teachers typically demonstrate better logical reasoning and a deeper understanding of mathematical concepts, indicating their readiness for teaching (Lestari et al., 2018). Targeted teaching, which may include courses on mathematical literacy, helps increase individuals' understanding and capacity to organize relevant issues (Ozgen, 2019). Involvement in designing activities and problem-solving tasks provides them with experience-based knowledge vital to developing teaching skills (Canbazoğlu & Tarim, 2020). Further, the experience of lesson modelling enables them to articulate mathematical arguments more and connect theoretical ideas to real-life contexts, thus better preparing them (Aydoğan Yenmez & Gökçe, 2023). This highlights the importance of enhancing the mathematical literacy of prospective teachers through effective planning in educational programs, including courses on mathematical literacy and experiential learning activities such as creating culturally embedded lessons and modeling. However, many prospective teachers need help improving students' mathematical literacy due to various challenges.

Some studies have revealed that prospective teachers struggle with completing PISA tasks, indicating a need to improve their mathematical knowledge and problem-solving skills (Aydın & Özgeldi, 2019). Many of them feel unprepared because of mathematical anxiety and a lack of self-confidence in their mathematical abilities (Ören Vural & Sevgi, 2024). Moreover, since mathematical skills and understanding contribute to their readiness, low levels of mathematical literacy indicate that their capacities should be enhanced (Suharta & Suarjana, 2018). Now, the central obstruction becomes the incomprehension of the mathematical processes and skills needed for teaching mathematical literacy, while some demonstrate fluency in problem-solving (Güler & Arslan, 2019).

In reality, several prospective teachers still struggle to generate pertinent and influential mathematical problems, which is an indicator of the missing competencies (Hall & Zmood, 2019). Ultimately, insufficient mastery of basic algorithms related to elementary school mathematics may hinder teachers' ability to successfully teach these concepts to their students (Astambayeva et al., 2021). That is why preparing prospective teachers requires a complex approach, including psychological support to address mathematical anxiety, enhanced training on PISA tasks, and providing educational materials, all of which facilitate a deeper understanding of mathematical procedures.

QR6. Preparation by Teacher Education Programs

Teacher education programs are currently engaging in practices that impact the preparation of future teachers to achieve maximum mathematical literacy. According to the reviewed articles, improvements in future teachers' knowledge and skills, the

integration of cultural and visual contexts, and curriculum strengthening all contribute to mathematical literacy.

First, the development of knowledge and skills becomes the primary focus; for example, teacher education programs emphasize the integration of contextual and procedural knowledge, intending to improve prospective teachers' understanding of mathematics and how to teach it (Aydın & Özgeldi, 2019; Aydoğan Yenmez & Gökçe, 2023). Furthermore, prospective educators receive training to develop advanced cognitive abilities, including problem-solving and critical thinking, essential for effective mathematics instruction. Problem-based and cooperative learning approaches equip individuals with important competencies (Canbazoğlu & Tarim, 2020; Rahmawati et al., 2023). In line with this, specialized training on algorithms and mathematical concepts has been incorporated into the educational curriculum for prospective teachers, providing theoretical understanding while acquiring practical skills during the learning process (Astambayeva et al., 2021; Ören Vural & Sevgi, 2024).

The second is achieved by incorporating mathematical literacy as a core component of teacher education programs. Other programs would also include more specific coursework that focuses on developing mathematical literacy, along with the proper use of language and mathematical symbols in teaching practice (Güler & Arslan, 2019; Lestari et al., 2018; Ozgen, 2019; Suharta & Suarjana, 2018). This ensures that prospective teachers not only understand mathematics but can also teach it in a relevant and applicable manner. Third, integrating cultural and visual contexts into mathematics instruction is crucial for enhancing mathematical literacy preparation. Teacher education inspires prospective teachers to incorporate the cultural context into learning, such as utilizing local artifacts, to connect with students' lives and foster creativity (Kurniawan et al., 2024).

Furthermore, it stresses the visual approach to mathematics education. It leads prospective teachers to use visual representations while developing their understanding of mathematical concepts, thereby enhancing their practice in mathematics teaching (Ilhan et al., 2019). Finally, preparing prospective teachers for tests and challenges within the teaching practice comes with resource support and assessment. More resources of this nature are available, which teacher education programs help foster aspiring teachers, pass graduation exams like LANTITE, and support a career in teaching (Hall & Zmood, 2019).

The methods used in teacher education to prepare future teachers for mathematical literacy suggest that such preparation encompasses a comprehensive and integrated system. Effective teaching requires combining content knowledge, pedagogical knowledge, and pedagogical content knowledge (Lojo, 2011). Developing in-depth mathematical knowledge, high-level thinking skills, and applying contextual and visual approaches demonstrates an effort to ensure that prospective teachers not only understand mathematical theories but also apply them effectively. However, it can also teach them in a relevant and creative way. Strengthening the curriculum by adding a mathematical literacy course also reflects the importance of emphasizing teaching based on a broader range of competencies, which will facilitate the development of students' mathematical literacy in the classroom. Resource support, provided in the form of practice tests and exam strategies, is also critical in preparing prospective teachers to face the challenges of exams and implement learning in the field.

Efforts to strengthen mathematical literacy are also reflected in curriculum innovations, such as including a dedicated mathematical literacy course designed to expand prospective teachers' competencies in applying mathematics in real-life contexts and encourage reflection on their roles as educators. Furthermore, resource support—such as the provision of practice questions, exam simulations, and strategies for dealing with professional assessments—also plays a role in strengthening their readiness to face challenges both in the certification process and in authentic teaching practice in the field. However, several challenges remain. One key challenge is ensuring that the mathematical literacy training provided is not merely superficial but truly strengthens deep conceptual understanding, meaningful contextual connections, and reflective problem-solving strategies. Winter (2014) emphasized that teacher education programs must explicitly strengthen fundamental mathematical knowledge, an understanding of the various contexts in which mathematics is used, and problem-solving skills as part of comprehensive mathematical literacy. Furthermore, consistent implementation of mathematical literacy programs across teacher education institutions also needs to be maintained to ensure equitable and sustainable quality.

Research Limitations

This study has several limitations that must be acknowledged as part of intellectual honesty. First, the number of reviewed articles was limited to publications available in selected databases within a specific timeframe, which may not fully represent the global development of ICT integration for regulated learning in mathematics education. Second, although a systematic review process was followed, potential bias in article selection and interpretation cannot be eliminated. Third, this study has not thoroughly examined how socioeconomic and cultural contexts influence the effectiveness of similar technological interventions, despite these factors being critical in determining the success of educational approaches across different countries (Jurdak & Shahin, 2001; Bakker, Cai, & Zenger, 2021).

Future Research Directions

Based on the findings and limitations above, future research is recommended to: (1) broaden the scope by including articles published in multiple languages and from a broader range of databases; (2) investigate the effectiveness of ICT-based approaches in diverse socioeconomic and cultural settings, in order to explain how local characteristics influence regulated learning processes; (3) conduct empirical studies to examine the direct implementation of ICT for supporting self-regulated and co-regulated learning in mathematics classrooms; and (4) explore how the success of digital interventions may relate to other variables such as teacher digital readiness, types of devices used, and national curricula. These directions could generate more context-sensitive and practical insights for educators and policymakers.

▪ CONCLUSION

This study answers a central question in mathematics education: *How prepared are prospective teachers to foster mathematical literacy in their future classrooms?* A review of 13 empirical studies, primarily from countries with moderate to low PISA performance, reveals that the mathematical literacy of prospective teachers is influenced

not only by academic training but also by cultural context, pedagogical orientation, and exposure to real-life problem-solving experiences. Stronger outcomes are linked to teacher preparation programs that embed interdisciplinary thinking, model-based reasoning, and PISA-aligned tasks into authentic learning experiences. These findings collectively affirm that mathematical literacy is not merely a competency to be tested—it is a mindset that future educators must internalize and transfer meaningfully to their students.

The implications of this research for teacher education policy and practice are that curriculum designers must ensure that mathematical literacy is integrated as a core, assessable element of teacher preparation, not being treated as an add-on. Teacher education institutions should develop modules and simulations that explicitly integrate mathematics concepts in real-world applications, especially within culturally relevant contexts, and provide differentiated support for prospective teachers depending on their readiness levels. Providing structured opportunities for reflection, microteaching, peer collaboration, and scaffolding of complex tasks can bridge the gap between theoretical understanding and classroom practice. Although this review is limited by the geographical concentration of studies and the absence of longitudinal data, it opens up meaningful directions for future research, particularly in exploring how literacy-focused interventions shape professional identity and classroom effectiveness over time. Ultimately, strengthening the mathematical literacy of prospective teachers is not only about enhancing individual competencies but also about shaping future classrooms where students experience mathematics as a relevant, empowering, and socially meaningful discipline. If we invest in teachers' capacity to teach mathematics with insight and purpose, we invest in a more numerate, critical, and thoughtful generation ahead.

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