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Mathematical literacy and its influencing factors: A decade of research findings (2015-2024)

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Abstract

This systematic review investigates recent empirical research on mathematical literacy, focusing on real-life problem-solving, instructional methods, influencing factors, and assessment practices. Drawing from 37 peer-reviewed studies published between 2015 and 2024, the review synthesizes findings related to frequently studied constructs, targeted mathematical domains, educational levels, and the effectiveness of various pedagogical interventions. The results indicate that mathematical literacy, achievement, and problem-solving are the most commonly examined outcomes, with algebra and geometry being the most frequently addressed content areas. Instructional approaches such as realistic mathematics education, problem-based learning, and STEM-integrated models consistently show positive impacts on students' mathematical literacy. However, students continue to struggle with context-based problem formulation and interpretation. Cognitive factors such as executive function and self-efficacy, along with contextual variables like socio-economic status and language proficiency, significantly influence student outcomes. The review also highlights gaps in assessment practices and the need for improved teacher training. Implications for policy, practice, and future research are discussed to support the development of mathematical literacy as a key 21st century competency.

Keywords: mathematical literacy, real-life mathematics, instructional methods, assessment, problem-solving, systematic review

INTRODUCTION

In an era marked by rapid technological change and complex societal challenges, mathematical literacy has emerged as an important competency for individuals navigating the demands of the 21st century. More than the ability to perform routine calculations, mathematical literacy encompasses the capacity to formulate, apply, and interpret mathematics in real-world contexts, a skill set essential for informed decision-making, active citizenship, and professional success. The Organization for Economic Co-operation and Development (OECD), through its program for international student assessment (PISA), has positioned mathematical literacy at the forefront of international educational assessment and reform, viewing it as a core indicator of students' readiness for future life challenges.

The relevance of mathematical literacy extends beyond academic achievement; it is fundamental to developing critical thinking, problem-solving abilities, and reasoning skills necessary for interpreting quantitative information in everyday life (Gur et al., 2023). As Rizki and Priatna (2019) argue, the focus of mathematics education must shift from procedural fluency to the meaningful application of knowledge in diverse contexts. This perspective has been reinforced by

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Contribution to the literature

- This systematic review synthesizes a decade of empirical and conceptual research (2015–2024) on mathematical literacy, identifying dominant constructs, content areas, and instructional interventions across various educational settings.
- The study integrates findings from 37 peer-reviewed studies, showing thematic findings about real-life problem-solving, equity challenges, and assessment practices.
- The study indicates under explored areas such as higher education contexts and advanced mathematical domains like calculus, pointing to important gaps in the existing literature.
- The study advances the field by emphasizing the importance of inclusive, context-rich instructional strategies and culturally responsive assessment models aligned with 21st-century educational goals.

global events, such as the COVID-19 pandemic, where interpreting exponential growth, understanding data trends, and making risk-related decisions required a foundational grasp of mathematical concepts (Heyd-Metzuyanim et al., 2021).

Despite its growing importance, improving and assessing mathematical literacy remains a complex task. Students frequently struggle with context-based mathematical problems, and many instructional approaches still emphasize rote procedures over applied reasoning. Moreover, factors such as socio-economic status (SES), language proficiency, cognitive styles, and executive function can significantly affect students' mathematical literacy outcomes (Kusuma et al., 2022; Zhang, 2018). Teachers' perceptions, curriculum structures, and assessment tools also play a vital role in shaping how mathematical literacy is taught and evaluated across educational systems.

Given the increasing emphasis on preparing students for real-world problem-solving and informed participation in society, it is essential to understand how mathematical literacy is being addressed in empirical and conceptual research. This study provides a systematic review of literature published between 2015 and 2024 that explores the development, assessment, and instructional strategies related to mathematical literacy, with a particular focus on real-life mathematics tasks. The review aims to synthesize key findings, identify trends and gaps in the literature, and presents how mathematical literacy can be effectively integrated into educational practice.

The following research questions guided this study.

1. What are the most commonly studied constructs, mathematical domains, and educational levels in studies on mathematical literacy?
2. How effective are different instructional approaches in improving students' mathematical literacy?
3. What cognitive, affective, and contextual factors influence students' performance in mathematical literacy?
4. How do assessment practices and teacher perceptions affect the teaching and evaluation of mathematical literacy?

LITERATURE REVIEW

Conceptualizing Mathematical Literacy

Mathematical literacy has gained prominence in educational discourse as a necessary competency for participating effectively in modern society. As defined by PISA, mathematical literacy is "an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts," including reasoning mathematically and using mathematical tools to describe, explain, and predict phenomena (OECD, 2013).

Beyond standard definitions, mathematical literacy has been theorized as a dynamic and context-dependent competence that bridges school mathematics with real-world applications. According to Kolar and Hodnik (2021), mathematical literacy involves not only mathematical knowledge but also the insightful readiness to act upon mathematical challenges in diverse, often non-mathematical, situations.

While sometimes used interchangeably, the terms *mathematical literacy*, *numeracy*, and *mathematical competence* have nuanced distinctions. Numeracy is often described as the ability to apply basic arithmetic skills in everyday life and is particularly used in adult education contexts (Genc & Erbas, 2019). It involves number sense, estimation, and understanding of practical mathematical ideas (Bisaillon, 2023; de Lange, 2003).

Mathematical competence, as framed by Niss and Højgaard (2019), refers to the ability to pose and solve mathematical problems and to engage meaningfully with mathematical language, symbols, and tools. In contrast, mathematical literacy includes and extends these capabilities by focusing on their application in real-life contexts and decision-making processes (Bolstad, 2023). According to Börner et al. (2019), mathematical literacy is similar to other literacies (e.g., textual and visual literacy) in that it requires both understanding and applying knowledge. It involves a dual capacity: to interpret and reason about mathematical content, and to actively use mathematics in practical, often interdisciplinary contexts.

Importance of Mathematical Literacy in Education

Mathematical literacy is increasingly recognized as a fundamental component of 21st century skills, essential for both academic success and personal development. According to Rizki and Priatna (2019), mathematical literacy is not only about performing calculations, but also about understanding when and how to apply mathematical knowledge to make informed decisions in life and work. It supports the development of essential competencies such as creativity, innovation, communication, collaboration, and adaptability–skills considered vital in today's fast-changing world.

In alignment with this, Komarudin et al. (2024) stated that mathematical literacy improves autonomous, critical, and creative thinking, thereby contributing to students' preparedness to face modern-day challenges. Their study, which integrated the reading, mind mapping, and sharing (RMS) teaching model with brainstorming techniques, found significant improvements in students' mathematical and digital literacies.

Mathematical literacy goes beyond academic relevance and extends into social, civic, and professional spheres. It is an important life skill that enables individuals to engage actively in democratic societies, make sound financial decisions, and participate effectively in the workforce. As noted by Sumirattana et al. (2017), mathematical literacy equips students to apply classroom knowledge to real-life problems, enhancing their ability to understand and evaluate everyday situations involving numbers, data, and patterns.

Heyd-Metzuyanim et al. (2021) provided compelling evidence during the COVID-19 pandemic, where understanding exponential growth, infection rates, and health-related statistics required a solid foundation in mathematical literacy. Their research indicated that adults with stronger mathematical identities and educational backgrounds were more capable of interpreting pandemic-related data and making informed decisions.

Furthermore, PISA-like assessments and real-world tasks using local contexts, such as the sailing-themed problems developed by Efriani et al. (2019), demonstrate the value of situating mathematics in meaningful scenarios. These tasks help students see the relevance of mathematics to their personal and cultural experiences, improving engagement and practical understanding.

Globally, educational policies and reforms have increasingly prioritized mathematical literacy as a critical learning outcome. For instance, PISA assessments conceptualize mathematical literacy as a key competency for navigating modern society, and many national curricula now emphasize its integration across subjects (Jackson et al., 2021; Sumirattana et al., 2017). The OECD and various national education bodies advocate for instructional approaches that promote the use of mathematics in diverse contexts, reflecting a shift from rote learning to application-based understanding.

In this regard, Jackson et al. (2021) introduced an equity-oriented STEM literacy framework that explicitly includes mathematical literacy as a foundational component. This framework not only supports academic achievement but also seeks to empower underrepresented and minoritized groups, ensuring that all students have equitable access to the tools necessary for future participation in STEM fields and beyond.

Moreover, educational models such as the RMS approach (Komarudin et al., 2024) and realistic mathematics education (RME) (Sumirattana et al., 2017) illustrate how policy-driven reforms can be translated into effective pedagogical strategies. These models demonstrate that when students are engaged with meaningful content and innovative instructional methods, their mathematical literacy significantly improves, thereby meeting both policy goals and societal needs.

Assessment of Mathematical Literacy

Mathematical literacy is most widely assessed through international large-scale assessments, with PISA being the most influential. PISA evaluates the ability of 15-year-old students to apply mathematical knowledge and skills in real-world contexts (OECD, 2016). The PISA framework assesses mathematical literacy across three key dimensions: processes (e.g., formulating, employing, and interpreting mathematics), content (e.g., quantity, space and shape, change and relationships), and context (e.g., personal, societal, scientific) (Ekmekci & Carmona, 2014).

In addition to PISA, many countries have adopted national-level assessments aligned with the PISA framework or have developed their own instruments. For example, Suciati et al. (2020) developed a validated and reliable mathematical literacy instrument in Indonesia that met the criteria for content and construct validity, making it suitable for formative classroom assessments. Similarly, Oktiningrum et al. (2016) developed culturally contextualized PISA-like tasks to assess students' mathematical literacy using Indonesian cultural heritage contexts, ensuring both local relevance and global alignment.

Other efforts include classification systems for assessment tasks, such as those proposed by Altun and Bozkurt (2017), who suggested six factors-algorithmic operations, mathematical inference, and real-world interpretation, that can help in categorizing and developing assessment instruments for six factors middle school learners.

Despite the structured frameworks, significant challenges remain in assessing real-life problem-solving and reasoning. As Venkat et al. (2009) argue, many assessments underrepresent higher-order skills such as reasoning and reflection due to the dominant focus on lower-order tasks like factual recall and routine procedures. This misalignment limits the ability of such assessments to capture the full spectrum of mathematical literacy as it is defined in curricula and policy documents.

Moreover, Bansilal and Debba (2012) found that the contextual attributes of tasks, such as unfamiliar scenarios, dense information, or culturally distant references, can negatively affect students' ability to interpret and respond to items, particularly among learners from disadvantaged backgrounds. These contextual complexities may introduce construct-irrelevant variance, thereby skewing the assessment of actual mathematical competence.

Ekmekci and Carmona (2014) also demonstrated that even PISA's multidimensional framework may not fully align with the statistical structure of students' test performances, raising questions about construct validity and the consistency between intended and measured dimensions.

At the school level, mathematical literacy is often embedded in general mathematics curricula and assessed through standardized tests or PISA-inspired tasks. In contrast, university-level assessment tends to focus more on abstract mathematics or discipline-specific problem solving, often neglecting the broader, applied perspective central to mathematical literacy. Umbara and Suryadi (2019) reported that many Indonesian teachers lack familiarity with the PISA framework and do not systematically incorporate literacy-based assessments in classroom practice, even though they may value its learning outcomes. The discrepancy between teaching practices and assessment processes contributes to an inconsistent emphasis on mathematical literacy across education levels. Haara et al. (2017) further emphasized that while school-level research and policy frequently focus on preparing students for national and international assessments, universities seldom assess mathematical literacy as a core construct. Instead, assessments are typically geared toward procedural fluency and content mastery, leaving a gap in evaluating whether students can transfer their knowledge to real-world, interdisciplinary problems.

Empirical Studies in School and University Contexts

Empirical studies conducted in K-12 environments emphasize the complex development of mathematical literacy through context-rich tasks, curricular integration, and student-centered approaches. For example, Kolar and Hodnik (2021) investigated how Slovenian sixth graders approached contextual versus non-contextual problems. The findings indicated that while students often succeeded in non-contextual tasks, they struggled to recognize and apply mathematical content in real-world contexts, revealing a gap between procedural knowledge and applied literacy.

Similarly, Wardat and Alali (2024) found that both self-efficacy and classroom learning environments significantly influence students' mathematical literacy. Students with higher self-confidence and who experienced supportive instructional settings demonstrated greater engagement and success in solving contextual problems.

Pedagogical innovations such as problem-based learning (PBL), mathematical modeling, and the integration of real-world contexts have consistently shown to enhance students' mathematical literacy. Kaiser and Willander (2005) demonstrated that the inclusion of modeling tasks within an innovative teaching program led to substantial improvement in lower-level literacy skills. However, progress was limited at more advanced levels, particularly students' ability to translate between mathematical models and real-world situations.

In Hungary, the NA-MA POTI project serves as a systemic example of how national curriculum reform can improve mathematical literacy by embedding modeling and contextually rich problems into everyday instruction (Kolar & Hodnik, 2021).

The success of these pedagogical strategies relies heavily on teachers' understanding and implementation of literacy-oriented practices. Haara et al. (2017) emphasized that while teachers value the concept of mathematical literacy, many are unsure how to implement it effectively. Their review showed that teacher education programs often lack explicit focus on how to teach mathematical literacy, resulting in a disconnect between curriculum goals and classroom practices.

While mathematical literacy is commonly stressed in school-level curricula, research shows a relative shortage of focus in higher education. Stacey (2015) noted that PISA-based literacy models are rarely used in university settings, even in general education math courses. Instead, the focus often remains on formal mathematical content, disconnected from real-life application.

The integration of mathematical literacy varies significantly between STEM and non-STEM university programs. In STEM disciplines, mathematical tasks are typically content-heavy and assume prior abstract proficiency. In contrast, non-STEM programs may lack structured mathematical instruction altogether. According to the framework for diagnostic assessment (Csapó & Szendrei, 2011), university programs often fail to reinforce the real-world applications of mathematics, reinforcing a compartmentalized rather than interdisciplinary understanding.

Despite these limitations, the development of mathematical literacy in university students has been linked to critical thinking and overall academic success. Kolar and Hodnik (2021) observed that students who could successfully bridge mathematical concepts with contextual understanding performed better in complex problem-solving tasks. Their research advocates curriculum reforms at the tertiary level to promote mathematical modeling, reasoning, and critical interpretation as core outcomes. Moreover, Kaiser and Willander's (2005) findings support this claim, showing that when university students engage with contextual problems early in their academic journey, they become more competent in making analytical decisions in later professional settings.

Factors Influencing Mathematical Literacy

A broad SES body of international research shows that student-related characteristics significantly impact mathematical literacy. Psychological and affective factors such as self-efficacy, interest in mathematics, anxiety, and motivation have been consistently identified as key predictors (Sezgin, 2017; Zhang, 2018). For instance, students with high self-efficacy and low anxiety typically perform better on mathematical literacy tasks. Zhang's (2018) hierarchical linear modeling of PISA 2012 data from China found that students' perceived behavioral control (including mathematics self-efficacy and self-concept) was a strong positive predictor of mathematical literacy.

SES is another critical factor. Aksu et al. (2022) used data mining techniques to analyze PISA 2015 data across six countries and found SES to be a dominant predictor of students' mathematical literacy in most contexts. Similarly, Lara-Porras et al. (2019) showed that students from higher SES backgrounds, with access to books, the internet, and educated parents, performed significantly better across Spanish regions.

Cultural and linguistic contexts also play a role. Nyandoro (2019) demonstrated a strong correlation between English language proficiency and mathematical literacy performance among grade 12 students in South Africa.

Institutional and school-level factors significantly shape students' opportunities to develop mathematical literacy. These include availability of educational resources, curriculum design, teacher qualifications, and school environment. Guo (2015) conducted a multilevel analysis of PISA 2012 data and found that a lack of educational resources negatively affected student outcomes in all countries studied. Factors such as school type, class size, and student-teacher ratio were also found to mediate the relationship between students' backgrounds and their literacy scores.

Curriculum emphasis also matters. Zhang (2018) reported that exposure to applied mathematics tasks, along with cognitive activation during lessons, was positively associated with student performance. However, constructivist instructional practices, when not well-supported, showed negative effects.

Furthermore, regional disparities in educational resources and teacher availability (especially in rural or underfunded schools) can exacerbate performance gaps. As shown in the Spanish context (Lara-Porras et al., 2019), school location (urban vs. rural) and governance structures around curriculum and assessment autonomy were important predictors of regional performance differences.

The integration of technology and digital tools into mathematics education plays an increasingly important role in shaping mathematical literacy. According to Zhang (2018), digital learning environments, especially those that encourage self-regulated learning and problem-solving, can improve students' conceptual understanding and application skills. Schools that provide access to digital learning platforms and promote extracurricular math-related activities (e.g., coding, logic games) offer students broader opportunities to develop literacy competencies. However, the effectiveness of technological tools depends on both infrastructure and teacher digital competencies. Nyandoro (2019) reported that students in under-resourced schools, even when given access to digital tools, often lacked the guided instruction needed to fully benefit from them, particularly in linguistically challenging contexts.

METHOD

This systematic review synthesizes empirical and conceptual research on mathematical literacy, emphasizing its application to real-life math problems in educational contexts. The methodology follows a structured process for identifying, selecting, and analyzing studies, guided by the preferred reporting items for systematic reviews and meta-analyses (PRISMA) framework.

Search Strategy

The literature search was conducted across seven databases to identify studies relevant to mathematical literacy. The databases included Google Scholar, ERIC, Web of Science (WoS), Scopus, EBSCOHOST, DOAJ, and arXiv.org. Search terms were developed to capture the review's focus, including "mathematical literacy," "functional literacy," "real-life math problems," "context-based mathematics," and "problem-solving skills," combined with Boolean operators (e.g., AND, OR) and modified as needed for each database's syntax. Filters were applied to limit results to peer-reviewed journal articles published in English between 2015 and 2024. The search was completed on February 24, 2025, ensuring coverage of the specified time frame.

Table 1. Methodological quality rubric for study inclusion

Criterion	Description	Scoring levels
Clarity of research objectives	Are the research goals or questions clearly stated and aligned with the methodology?	2 = clearly stated, 1 = partially, 0 = not stated
Study design appropriateness	Is the chosen design (qualitative, quantitative, or mixed) appropriate for answering the research question(s)?	2 = strong alignment, 1 = partial, 0 = weak/mismatched
Sampling strategy	Is the sample clearly described and appropriate in size and selection method for the study purpose?	2 = clearly described and appropriate, 1 = partially, 0 = inadequate or not described
Validity and reliability of instruments	Are the tools or instruments validated, piloted, or justified for their use?	2 = fully addressed, 1 = somewhat, 0 = not addressed
Data analysis rigor	Are the methods of data analysis sound, systematic, and appropriate for the data collected?	2 = rigorous, 1 = adequate, 0 = weak or unclear
Transparency and reporting	Are the methods and findings reported in sufficient detail to allow for replication or judgment of trustworthiness?	2 = fully transparent, 1 = moderate detail, 0 = poor or vague
Ethical considerations	Are ethical procedures (e.g., consent, approval) mentioned and appropriate?	2 = clearly stated, 1 = implied, 0 = not addressed

Identification

The initial search yielded 917 records across the databases: Google Scholar (n = 568), ERIC (n = 43), WoS (n = 22), Scopus (n = 115), EBSCOHOST (n = 79), DOAJ (n = 53), and arXiv.org (n = 37). These records represented a broad pool of potential studies, including articles, preprints, and other scholarly outputs. Duplicate records (n = 307) were identified and removed, leaving 610 unique records for further processing.

Inclusion Criteria

1. Relevance to mathematical literacy.
2. Empirical studies (quantitative, qualitative, or mixed-methods research).
3. Peer-reviewed journal articles.
4. Studies published between 2015-2024.
5. English-language publications.
6. Research focused on students and teachers.

Table 1 shows methodological quality rubric for study inclusion.

Screening

The 610 unique records were screened by reviewing titles and abstracts against the review's focus on mathematical literacy and real-life math problems in educational settings. This initial screening excluded 420 records that were clearly irrelevant, such as those not related to mathematics education, lacking an empirical focus, or outside the educational context of students and teachers. No automation tools were used for exclusion at this stage; all decisions were made manually by the research team to ensure accuracy.

Eligibility

Full-text reports were sought for the remaining 190 records to assess their eligibility in detail. Of these, 3 reports could not be retrieved due to access restrictions (e.g., paywalls or broken links), leaving 187 reports for evaluation. Each full-text article was reviewed against the inclusion criteria, with specific attention to study type (empirical or conceptual), publication type (peer-reviewed journal), language (English), time frame (2015-2024), and relevance to real-life math problems in educational contexts involving students or teachers.

Inclusion

From the 187 reports assessed, 150 were excluded for the following reasons: review articles (n = 11), conference proceedings (n = 14), low-quality studies (e.g., lacking methodological rigor or sufficient detail) (n = 44), studies not focused on mathematical literacy (n = 35), publications outside the 2015-2024 range (n = 32), and non-English articles (n = 17). After this process, 37 studies were included in the final review. See the **Appendix** for the full list of the included studies. The PRISMA flow chart related to our source selection is presented in **Figure 1**.

Data Extraction and Analysis

The data extracted from the 37 included studies were analyzed using a descriptive and thematic synthesis approach. Data were extracted using a customized coding form developed to capture key variables. The form included fields such as study title, authors, year, country, journal, outcome categories (e.g., achievement, problem-solving skills), instruments used, study design, method type, math concepts discussed, school level, unit of analysis, number of participants, and effectiveness (positive, neutral, negative impact on learning). Two researchers independently extracted the data, with discrepancies resolved through consensus discussions.

The extracted data were analyzed descriptively to identify trends and patterns in mathematical literacy research. Studies were grouped by method type (quantitative, qualitative, mixed-methods), educational

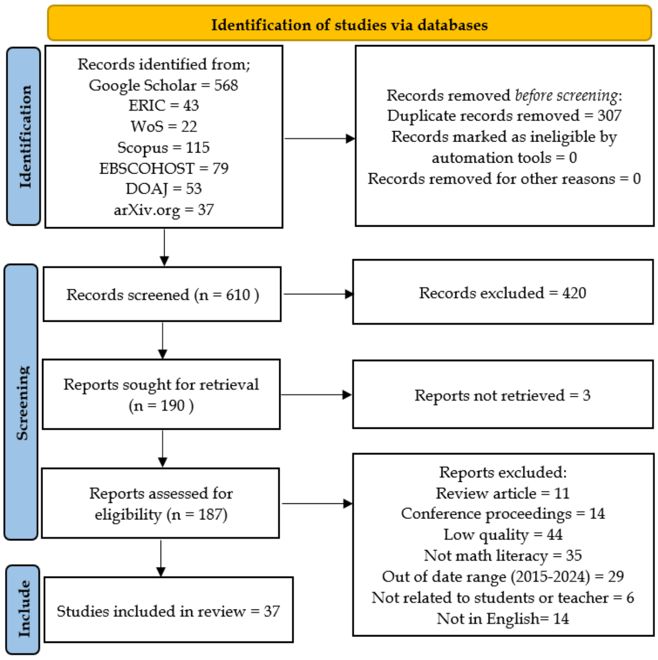

Figure 1. PRISMA for the systematic review (Adopted for https://www.prisma-statement.org/)

level, and mathematical concepts (e.g., algebra, geometry). A narrative synthesis was employed to summarize findings on effectiveness and specific outcomes like problem-solving skills and formulating real-life situations mathematically. In addition, a narrative synthesis was employed to interpret findings across diverse educational settings and methodologies. Thematic patterns were identified and organized to support the development of the discussion. Visual tools such as frequency charts and area plots were created to represent the trends and variability in the reviewed literature.

Limitations

Several limitations affected the review process. First, the reliance on English-language publications may have excluded relevant studies in other languages, potentially biasing the findings toward English-speaking regions. Second, the inability to retrieve 3 full-text reports may have omitted valuable data. Third, the heterogeneity of study designs and outcome measures disallowed quantitative synthesis, limiting the ability to draw definitive conclusions about effect sizes. Finally, the focus on peer-reviewed journal articles excluded grey literature (e.g., theses and reports), which might offer additional contribution to this study.

Quality Assessment

The quality of the studies included was assessed during the eligibility phase to ensure methodological consistency. Criteria included the clarity of research objectives, appropriateness of study design, validity and reliability of instruments, and robustness of reported findings. Studies deemed low quality (n = 44) were excluded based on issues such as insufficient methodological detail, lack of transparency in data collection, or weak statistical approaches. The remaining 37 studies were judged to meet acceptable quality standards, though variations in rigor (e.g., sample size, instrument validation) were noted and considered in the synthesis of findings.

RESULTS

Descriptive Analyses

Table 2 presents a summary of key characteristics derived from 37 studies exploring various mathematical constructs across diverse international contexts. It shows information on authorship, publication year, country, targeted mathematical constructs, study design and type, mathematical domains involved, participant demographics, and overall study effectiveness.

Table 2. Key characteristics

Author, year, country	Construct	Study design and type	Math	Participants	Effectiveness
Özenç and Çarkıt, 2021, Turkey	Problem-solving skills	Empirical (quantitative)	Not specified	744 grade 4 students	Positive
Kolar and Hodnik, 2021, Slovenia	Problem-solving skills	Empirical (mixed-methods)	Algebra	72 grade 6 students	Neutral
Sa'diyah et al., 2024, Indonesia	Problem-solving skills, reasoning	Empirical (qualitative)	Not specified	24 students (14-16 years old)	Negative
Faragher, 2019, Australia	Achievement, reasoning	Conceptual (qualitative)	Algebra	Learners with Down syndrome	Positive
Güler and Arslan, 2019, Turkey	Perception	Testing (qualitative)	NA	63 pre-service teachers	Positive, neutral
Mumcu, 2016, Turkey	Problem-solving skills	Theoretical (qualitative)	Algebra, geometry, statistics	119 grade 6 students	Positive
Nurmasari et al., 2024, Indonesia	Achievement	Empirical (mixed-methods)	Geometry	104 students	Positive
Özaydın and Arslan, 2022, Turkey	Reasoning	Conceptual (mixed-methods)	Algebra	30 teachers	NA

Table 2 (Continued). Key characteristics

Author, year, country	Construct	Study design & type	Math	Participants	Effectiveness
Awgichew, 2022, Ethiopia	Curriculum functionality	Empirical (qualitative)	Algebra, measurement	8 teachers	Neutral
Siswono et al., 2018, Indonesia	Perception	Empirical (quantitative)	Algebra, geometry, probability, statistics	91 teachers	NA
Matope and Chiphambo, 2022, South Africa	Perceptions	Empirical (quantitative)	Probability, measurement	28 grade 12 students	NA
Roth et al., 2015, Canada	Achievement	Empirical (mixed-methods)	Algebra, geometry, probability, statistics	33 grade 10 students	NA
Sumirattana et al., 2017, Thailand	Achievement	Empirical (mixed-methods)	Algebra, geometry	104 grade 9 students	Positive
Yenmez and Gökçe, 2023, Turkey	Achievement	Empirical (mixed-methods)	Algebra, geometry, probability, statistics	113 pre-service teachers	Positive, neutral
Ozgen, 2019, Turkey	Problem-solving skills	Empirical (qualitative)	Algebra, measurement	18 Student and pre-service teachers	Positive
Zainiyah and Marsigit, 2019, Indonesia	Problem-solving skills	Empirical (quantitative)	Algebra, geometry, statistics, measurement	35 grade 5 students	Positive
Warniatun and Junaed, 2020, Indonesia	Mathematical literacy	Empirical (mixed-methods)	Geometry	60 grade 8 students	Positive
Rahayu et al., 2020, Indonesia	Mathematical literacy	Empirical (mixed-methods)	Algebra, geometry	74 grade 11 students	Positive
Saputri et al., 2018, Indonesia	Mathematical literacy	Empirical (qualitative)	Algebra, geometry, probability, statistics	7 grade 7 students	NA
Lara-Porras et al., 2019, Spain	Mathematical literacy	Empirical (quantitative)	Algebra, geometry, statistics	9,123 student (15-year-old)	NA
Genc and Erbas, 2019, Turkey	Perception	Empirical (qualitative)	Algebra, geometry	16 Teacher	NA
Dewi and Maulida, 2023, Indonesia	Achievement	Empirical (mixed-methods)	Algebra	Not specified	Positive
Zikl et al., 2015, Czech Republic	Achievement	Empirical (quantitative)	Geometry, statistics, measurement	48 grade 4 students	Negative
Sönmez and Yılmaz, 2023, Turkey	Perception	Empirical (qualitative)	Geometry, statistics	201 teachers	NA
Tai and Lin, 2015, Taiwan	Problem-solving skills	Empirical (quantitative)	Algebra, geometry, probability, statistics	193,370 grade 9 and 10 students	Not specified
Colwell and Enderson, 2016, USA	Perception	Empirical (qualitative)	Algebra, geometry, probability, statistics	7 pre-service teachers	NA
Lin and Tai, 2015, Taiwan	Achievement	Empirical (quantitative)	Algebra, geometry, probability, statistics	192,819 grade 9 and 10 students	Positive
Khaesarani and Ananda, 2022, Indonesia	Problem-solving skills	Empirical (qualitative)	Algebra	4 grade 7 students	Negative
Susanta et al., 2023, Indonesia	Engagement	Empirical (mixed-methods)	Algebra	62 grade 6 students	Positive
Canbazoglu and Tarım, 2020, Turkey	Achievement	Empirical (mixed-methods)	Algebra, probability	73 pre-service teachers	Positive
Laurens et al., 2018, Indonesia	Achievement	Empirical (qualitative)	Geometry	50 grade 11 students	Positive
Kozaklı Ulger et al., 2022, Turkey	Perception	Conceptual (qualitative)	Algebra, geometry, statistics	28 teachers	Positive
Fauzi and Chano, 2022, Indonesia	Achievement	Empirical (quantitative)	Geometry	50 grade 5 students	Positive
Kusuma et al., 2022, Indonesia	Achievement	Empirical (qualitative)	Geometry, statistics	30 grade 8 students	NA
Jailani et al., 2020, Indonesia	Achievement	Empirical (quantitative)	Algebra, geometry, statistics	1,001 grade 8, 9, 10 students	NA
Suharta and Suarjana, 2018, Indonesia	Achievement	Empirical (mixed-methods)	Algebra, geometry, probability, statistics	12 pre-service teachers	NA
Altun and Bozkurt, 2017, Turkey	Achievement	Empirical (quantitative)	Algebra, geometry, probability, statistics	435 grade 8 students	Neutral

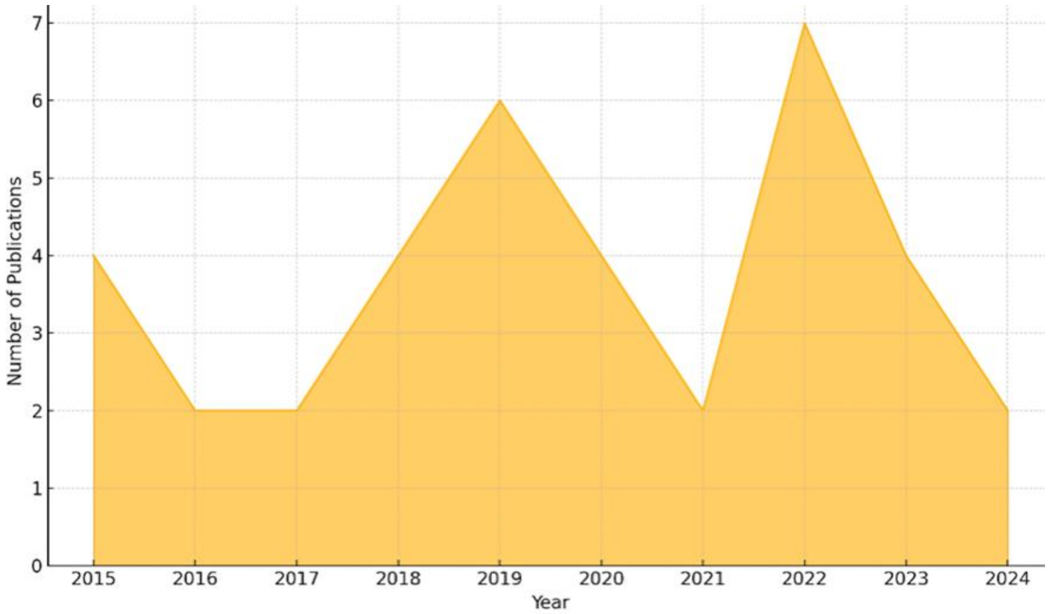

Figure 2. Area plot of publications over the years (Source: Authors' own elaboration)

Several key results can be drawn from **Table 2**.

1. The most frequently addressed constructs in the reviewed studies include problem-solving skills, achievement, perception, reasoning, and mathematical literacy. Among these, problem-solving and achievement emerge as dominant themes.
2. Most studies employed empirical designs, predominantly using quantitative and mixed-method approaches. Qualitative research is primarily used to explore deeper perceptions and reasoning skills.
3. Algebra and geometry are the most frequently addressed mathematical areas in the studies, followed by statistics and probability. Notably, calculus is absent from most of the studies, suggesting that the focus is mainly on elementary and secondary education contexts.
4. Research largely involves diverse participant groups, including students from various grade levels (primarily middle and high school), teachers, and pre-service teachers. Participant numbers vary significantly from small-scale qualitative groups (e.g., 7-30 participants) to large quantitative samples (e.g., over 190,000 students).
5. Many studies reported positive outcomes regarding the effectiveness of interventions or instructional methods. However, neutral or negative results were also identified, notably in studies focusing on problem-solving skills and reasoning.

The reviewed studies cover a diverse set of countries. Notably, a significant proportion of the studies originate from Indonesia and Turkey, indicating a strong regional emphasis on exploring educational outcomes and instructional practices in mathematics. Other countries represented include Australia, Canada, Slovenia, South Africa, Spain, Taiwan, Ethiopia, and the United States.

The analysis of study effectiveness revealed varied impacts of the interventions and approaches investigated across the reviewed articles. A substantial number of studies reported positive effects on learning outcomes, such as those by Özenç and Çarkıt (2021), Mumcu (2016), Nurmasari et al. (2024), and Dewi and Maulida (2023). A smaller group of studies indicated neutral outcomes, including Kolar and Hodnik (2021) and Altun and Bozkurt (2017), where no significant change was observed. A few studies, such as Sa'diyah et al. (2024) and Khaesarani and Ananda (2022), reported negative effects. Additionally, several studies, including Özaydın and Arslan (2022), Siswono et al. (2018), and Lin and Tai (2015), did not measure any effectiveness.

Figure 2 visualizes the area plot of the distribution and trends of scholarly publications included in this review over different years.

From **Figure 2**, it is evident that the number of publications significantly varies over the period examined (2015-2024). Notably, 2022 emerges as the most productive year, with seven publications. The years 2019 and 2018 also demonstrate considerable contributions, with six and four publications, respectively. In contrast, the lowest research outputs are observed in 2016, 2017, 2021, and 2024, each with only two publications.

The horizontal bar chart in **Figure 3** presents the frequency of different outcome categories targeted in the reviewed studies. Each outcome category is displayed alongside the corresponding study IDs that contributed to it.

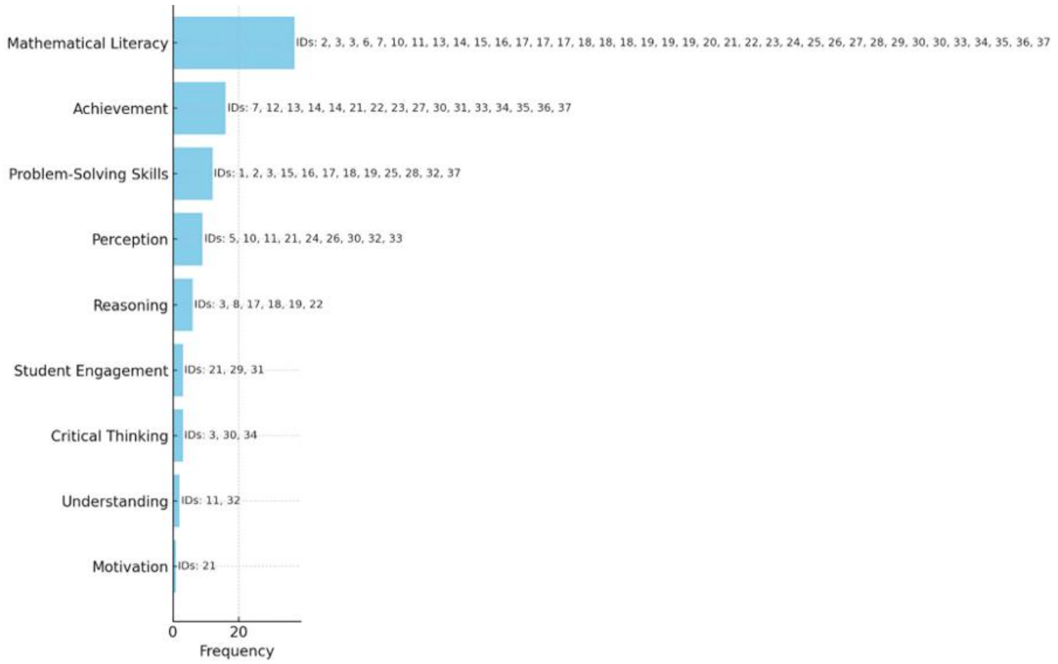

Figure 3. Outcomes (Source: Authors' own elaboration)

As shown in **Figure 3**, the most frequently studied outcome is mathematical literacy, appearing in 37 instances across multiple studies. Achievement is the second most studied outcome, featured in 16 studies. problem-solving skills ranks third, with 12 studies addressing this critical cognitive skill essential for applying mathematics effectively. Other notable outcomes include perception (9 studies), reasoning (6 studies), and critical thinking and student engagement (3 studies each). Less frequently studied outcomes such as understanding and motivation (2 studies and 1 study, respectively) indicate areas that, while important, is underrepresented in recent research.

The donut chart in **Figure 4** illustrates the distribution of key mathematical concepts, algebra, geometry, probability, statistics, and measurement, across selected research studies.

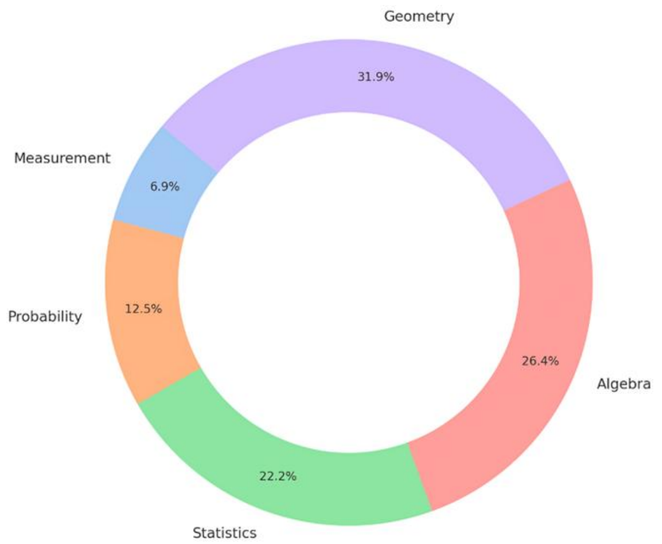

Figure 4. Distribution of key mathematical concepts (Source: Authors' own elaboration)

As shown in **Figure 4**, geometry is the most frequently studied mathematical concept, appearing in approximately 32% of the studies. Algebra follows closely with around 26%, reinforcing its foundational role in school mathematics and its connection to logical reasoning and problem solving. Statistics account for about 22% of the research focus while probability was addressed in roughly 13% of the studies. Measurement is the least addressed concept, comprising just under 7%.

THEMATIC ANALYSES

Relationship Between Mathematical Literacy and Other Cognitive Skills

Several studies have demonstrated the link between mathematical literacy and problem-solving competence. Students with higher functional literacy, for example, also tend to perform better on problem-solving tasks, indicating a reciprocal relationship between literacy and applied cognitive processes (Özenç & Çarkıt, 2021). Similarly, the ability to formulate context-based problems mathematically has been shown to be a critical subskill of literacy, however, this skill remains underdeveloped in many students (Sa'diyah et al., 2024).

Mathematical reasoning is also widely recognized as a core component of literacy. Reasoning allows students to generalize, make logical inferences, and communicate ideas. The development of structured rubrics to assess reasoning, aligned with the PISA framework, reflects growing awareness of the need to measure these competencies as part of broader literacy assessments (Özaydın & Arslan, 2022).

Cognitive characteristics such as executive function have a significant influence on literacy performance. Students with stronger working memory and cognitive flexibility are better equipped to navigate the multi-step, interpretive demands of literacy tasks (Kusuma et al., 2022).

Problem-solving styles and learning strategies have also been found to mediate students' mathematical literacy outcomes. Tai and Lin (2015) demonstrated that students with more independent problem-solving styles exhibit higher literacy scores, while Lin and Tai (2015) found that elaborative and self-regulatory learning strategies were positively associated with mathematical literacy.

In linguistically diverse settings, language proficiency can act as a cognitive filter in literacy assessments. Students who are linguistic minorities may struggle not with mathematics itself, but with the language of instruction and assessment, thus underestimating their true mathematical literacy (Roth et al., 2015).

Instructional Methods and Learning Models to Improve Mathematical Literacy

RME is one of the most prominent approaches used to bridge the gap between abstract mathematics and everyday experiences. By emphasizing problem-solving in meaningful, real-life contexts, RME encourages students to construct their own mathematical understanding. Studies by Sumirattana et al. (2017) and Laurens et al. (2017) demonstrated that RME significantly improves students' mathematical literacy and cognitive achievement by providing them with opportunities to engage in authentic tasks and develop formal mathematical knowledge from informal strategies.

Building on RME, researchers have integrated it with engineering design and technological tools to enhance its effectiveness. For instance, Nurmasari et al. (2024) proposed the realistic mathematics engineering model, which fuses RME with the engineering design process. Their results showed that this hybrid model significantly improved elementary students' mathematical literacy through iterative problem-solving and product creation. Similarly, Dewi and Maulida (2023) integrated STEM elements into mathematics instruction using ICT-assisted learning materials. The combination of STEM and the preprospec model (prepare, problem-solving, presentation, conclusion) led to improved student engagement and literacy performance.

PBL has also emerged as a powerful model for literacy development. By engaging students in inquiry-driven learning cycles, PBL improves deeper understanding of mathematical applications. Warniatun and Junaedi (2020) demonstrated that combining PBL with the think-talk-write approach resulted in notable gains in students' literacy levels. Rahayu et al. (2021) further showed that when PBL is supported by learning management systems (LMS), it not only improves literacy but also aligns well with students' cognitive styles–especially for visual and verbal learners.

Mathematical modeling and contextual tasks are central to bridging the gap between abstract mathematics and its real-world applications (Ekol & Greenop, 2023). Studies by Yenmez and Gökçe (2023) and Susanta et al. (2023) show that incorporating modeling tasks into instruction improves students' ability to represent and solve realistic problems. Supporting this, Mumcu (2016) offers a theoretical framework for understanding how mathematical literacy, modeling, and applications interrelate. His work shows that these are not isolated constructs but overlapping domains that share mathematical processes and skills.

Instructional innovation is also important in pre-service teacher education (Reyes, 2025). Canbazoglu and Tarim (2020) used activity-based practices to improve both the literacy levels and awareness of prospective elementary teachers. Their findings support the idea that collaborative, hands-on learning experiences are effective in improving literacy-focused teaching practices.

Finally, online learning environments have shown potential, especially during periods of educational disruption such as the COVID-19 pandemic. Fauzi and Chano (2022) observed that although online learning comes with challenges, it can still lead to measurable improvements in elementary students' mathematical literacy when thoughtfully implemented.

Teacher Perspectives and Professional Development

Studies show that teachers often have diverse and sometimes conflicting conceptions of mathematical literacy. Genc and Erbas (2019) categorized these into themes such as mathematical knowledge and skills, functional mathematics, problem-solving, reasoning and argumentation, innate mathematical ability, and motivation. This multiplicity of views can reflect richness, but it may also lead to ambiguities in classroom practices if not supported by coherent professional development.

Several investigations into teachers' understanding of mathematical literacy frameworks, particularly those inspired by PISA, indicate that even experienced teachers may struggle with interpreting or applying the frameworks effectively. Sönmez and Yılmaz (2023) found that while most teachers find the mathematical literacy proficiency level table comprehensible, they often fail to classify tasks accurately by level.

Preservice teachers, too, often enter the profession with limited or superficial understandings of mathematical literacy. Colwell and Enderson (2016) showed that despite some exposure to literacy concepts in coursework, pre-service teachers felt unprepared to incorporate mathematical literacy into their practice. Similarly, Güler (2019) found that prospective teachers had difficulty distinguishing between the competencies and processes required by mathematical literacy problems.

An important aspect of teacher professional development involves task design and problem-posing. Ozgen (2019) observed that while both teachers and pre-service teachers were capable of posing real-world mathematical problems, these problems often lacked structural depth or contextual sophistication. In a related study, Kozaklı Ulger et al. (2022) found that even with training, teachers tended to revert to traditional formats, crafting tasks with commands like "calculate" or "find," reflecting the inertia of textbook norms rather than the open-endedness of literacy-oriented tasks.

Innovative professional development models stress hands-on engagement and reflective practice. Canbazoglu and Tarim (2020) implemented activity-based training for pre-service elementary teachers, resulting in significant improvement in their mathematical literacy awareness, task design ability, and collaborative problem-solving. Similarly, Siswono et al. (2018) found that middle school teachers held generally positive attitudes toward context-based tasks but required more support in integrating these tasks into routine instruction.

Assessment and Measurement of Mathematical Literacy

A core development in this area has been the creation of rubric and assessment frameworks aligned with international standards such as PISA. Özaydın and Arslan (2022) developed a rubric based on the PISA 2021 mathematics framework, to evaluate students' mathematical reasoning across 12 criteria. Their work shows the need for structured, validated tools that can assess deeper mathematical competencies, rather than just content recall.

Other studies have focused on the measurement of students' proficiency across dimensions of content, process, and context. Jailani et al. (2020) analyzed students' literacy levels in relation to these three dimensions and found uneven development across grades, with the "formulate" process being particularly weak. Similarly, Zainiyah and Marsigit (2019) assessed mathematical literacy among fifth graders, using problem-solving indicators to evaluate their performance and identifying strengths in logic and communication and weaknesses in strategic application.

Classification systems and proficiency level descriptors have also gained attention as tools for both assessment and instructional planning. Sönmez and Yılmaz (2023) found that while many teachers could interpret the proficiency level tables, they struggled to apply them accurately when categorizing problems, indicating the gap between understanding assessment tools and using them effectively. Altun and Bozkurt (2017) proposed a new classification system for mathematical literacy problems based on six cognitive and structural dimensions (e.g., algorithmic operations, interpretation of mathematical language), providing a framework for both evaluation and curriculum development.

In parallel, research has explored assessment among specific learner populations. Zikl et al. (2015) compared mathematical literacy in pupils with mild intellectual disabilities versus their neurotypical peers using TIMSS tasks. Their findings revealed significant disparities, especially in reasoning and application, emphasizing the importance of differentiated assessment practices. Likewise, Faragher (2019) discussed how the rise of digital tools has transformed what counts as "functional mathematics" for learners with disabilities.

Beyond student assessments, there is increasing attention to the assessment literacy of teachers themselves. Studies like those by Güler (2019) and Sönmez and Yılmaz (2023) point out that even trained educators often lack the ability to distinguish between processes and competencies or to effectively classify task levels.

Equity and Access in Mathematical Literacy

Language and linguistic background are among the most frequently cited barriers to the equitable mathematical literacy development. Roth et al. (2015) conducted a multi-method investigation into the performance of linguistic minority students on PISA assessments and found that these students' mathematical competencies were often underestimated due to language barriers in test items. Similarly, Matope and Chiphambo (2022) examined how the language of instruction affects student understanding, showing that learners often struggle with the vocabulary and contextual passages of mathematical literacy tasks, especially when instruction is not delivered in their native language.

Students with disabilities face another set of accessibility challenges. Faragher (2019) argued for a redefinition of "functional mathematics" for students with Down syndrome, suggesting that assessments and curricula need to align more closely with digital tools and real-world functionality rather than traditional computations. Zikl et al. (2015) found similar challenges for students with mild intellectual disabilities, who consistently scored lower on mathematical literacy assessments, particularly in tasks requiring interpretation and reasoning.

Gender and socio-economic background also influence literacy outcomes. Suharta and Suarjana (2018) found that prospective elementary teachers with stronger mathematical skills demonstrated better mathematical literacy, and that female pre-service teachers slightly outperformed males. Meanwhile, Lara-Porras et al. (2019) conducted a regional analysis in Spain, revealing that SES, school location (urban vs. rural), and immigrant background were strong predictors of student performance in mathematical literacy. Their study, like others, advocates for policy-level interventions that account for regional disparities and educational disadvantages.

Curriculum and instructional practices also mediate access to mathematical literacy. Awgichew (2022) evaluated literacy and numeracy instruction in Addis Ababa and found that while textbooks showed some alignment with students' lives, classroom instruction lacked contextual relevance. Additionally, in the Indonesian context, Khaesarani and Ananda (2022) found that higher-order thinking skills (HOTS) problems are included in the curriculum, yet most students are only familiarized with low-level procedural problems.

While individual factors such as gender, language proficiency, disability status, and socioeconomic background were considered in this review, a more nuanced understanding emerges when these variables are analyzed inter-sectionally. Students do not experience educational disadvantage along a single axis; rather, the convergence of multiple identities, such as being a female student from a low-income household with limited language proficiency or a student with a disability attending an under-resourced rural school, can compound barriers to mathematical literacy. For instance, Roth et al. (2015) found that linguistic minority students faced significant challenges in interpreting assessment items, which were further exacerbated by socio-economic disadvantage. Similarly, Faragher (2019) emphasized that students with disabilities often require differentiated assessment tools, which are rarely available in contexts with limited resources. Lara-Porras et al. (2019) further demonstrated that regional disparities in Spain, shaped by school location, SES, and immigration status, led to significant differences in performance.

Student Performance and Difficulties in Mathematical Literacy

One recurring finding is that students tend to perform better on abstract, non-contextual problems than on contextualized tasks, which require them to extract relevant information and determine appropriate mathematical models. Kolar and Hodnik (2021) showed that while students may possess adequate mathematical knowledge, they struggle to apply it in unfamiliar, context-rich problems.

Other studies confirm that students face significant challenges in the "formulate" and "interpret" processes of mathematical literacy. Jailani et al. (2020) found that while some growth was observed across grades, students consistently performed weakest in the formulation phase. Saputri et al. (2018) reported that middle school students particularly struggled with the "space and shape" content area, not due to a lack of basic skills, but because they could not interpret or apply the problems to real-life contexts. Similarly, Sa'diyah et al. (2024) noted that many students lacked the ability to formulate real-world situations mathematically, which led to incorrect or incomplete solutions.

Executive function and cognitive style also influence student performance. Kusuma et al. (2022) found that students with low executive function struggled with multi-step reasoning and contextual problem solving. Rahayu et al. (2021) further revealed that both visualizer and verbalizer cognitive styles impacted the extent to which students could meet various components of mathematical literacy, particularly in a PBL-LMS environment.

Learning environments also matter. Fauzi and Chano (2022) reported that, during the COVID-19 pandemic, online learning environments led to moderate gains in mathematical literacy among elementary students, despite notable implementation challenges.

Assessment data also shows that students often lack HOTS needed for literacy-oriented tasks. Khaesarani and Ananda (2022) found that although HOTS problems are present in the curriculum, students are rarely trained to approach problems in non-routine, reflective ways, which hinders their literacy development.

Technology and Learning Environments

A key focus in this area has been the role of online learning, particularly during the COVID-19 pandemic. Fauzi and Chano (2022) found that elementary students who engaged in structured online mathematics instruction showed moderate improvements in mathematical literacy. However, they also noted that digital access, student motivation, and instructional design were significant mediating factors.

Beyond remote instruction, studies have explored integrating LMS and digital tools into PBL environments. Rahayu et al. (2021) demonstrated that PBL models supported by LMS tools not only improved students' literacy skills but also allowed for personalized learning paths based on students' cognitive styles. The LMS facilitated diverse forms of representation and communication, critical components of literacy, while providing teachers with assessment data to inform instruction.

Another notable trend is the development of technology-enhanced teaching materials aligned with STEM and mathematical literacy frameworks. Dewi and

Maulida (2023) designed digital materials using the preprospec learning model, which emphasizes preparation, problem-solving, presentation, and conclusion. The integration of STEM principles with ICT tools proved effective in both engaging students and improving their performance on mathematical literacy tasks. Technology also plays a role in shifting definitions of functional mathematics, especially for learners with disabilities. Faragher (2019) noted that devices such as calculators and mobile apps have redefined what it means to be mathematically literate in a digital world.

DISCUSSION

This systematic review aimed to synthesize empirical and conceptual research on mathematical literacy conducted between 2015 and 2024, with a particular focus on real-life mathematical tasks, influencing factors, instructional models, and assessment practices. A total of 37 peer-reviewed studies were analyzed, revealing important trends in research design, constructs, educational levels, and the effectiveness of various teaching interventions.

One of the most notable findings is the prominence of mathematical literacy, achievement, and problem-solving skills as the most frequently studied constructs. These focus areas reflect a growing international emphasis on developing students' ability to apply mathematical knowledge beyond the classroom. Algebra and geometry emerged as the most addressed domains, due to their foundational role in school mathematics and their strong connection to reasoning and modeling tasks. However, the absence of studies addressing higher-level domains such as calculus points to a continued emphasis on middle and secondary education contexts.

It is particularly noteworthy that, despite mathematical literacy being a core component of the PISA assessment framework and a critical indicator of students' readiness for real-world problem-solving, there appears to be a relative lack of research focusing on this area in Western countries as well as in nations that consistently perform at the top of the PISA rankings. This gap suggests a disconnect between assessment priorities and research agendas, indicating the need for more in-depth investigations into how high-performing education systems conceptualize, implement, and support the development of mathematical literacy.

In terms of instructional strategies, RME, PBL, and STEM-integrated models consistently show positive effects on students' mathematical literacy. These approaches emphasize contextualization, modeling, and active student engagement, key components aligned with the PISA framework. Studies such as those by Laurens et al. (2017) and Dewi and Maulida (2023) demonstrated how combining meaningful content with innovative pedagogy supports deeper understanding and improved performance.

Despite the success of these instructional models, the review also found persistent challenges in specific literacy processes, especially in students' ability to formulate and interpret real-life problems mathematically. This weakness, documented by Jailani et al. (2020) and Sa'diyah et al. (2024), shows a gap between procedural fluency and the flexible application of mathematics in novel situations. Such findings call for a more deliberate emphasis on strategic thinking and representational skills in instruction.

A range of cognitive and contextual factors were also found to influence students' mathematical literacy. Studies indicated the role of executive function, self-efficacy, language proficiency, and socio-economic background in shaping performance Students with stronger cognitive flexibility and working memory, both essential for multi-step reasoning, tended to perform better on literacy tasks. (Kusuma et al., 2022). Similarly, classroom environments that supported student autonomy and engagement were linked to higher literacy outcomes (Wardat & Alali, 2024).

Teacher-related factors played a critical role as well. While many teachers express positive views toward mathematical literacy, several studies revealed uncertainty about how to implement or assess literacy-oriented tasks. For example, Sönmez and Yılmaz (2023) found that teachers struggled to accurately classify task difficulty using the PISA proficiency level tables. This shows the need for professional development programs that focus not only on instructional strategies but also on assessment literacy and task design.

The review also highlighted ongoing equity challenges. Linguistic minority students, learners with disabilities, and students from lower socio-economic backgrounds often face barriers that hinder their mathematical literacy development (Faragher, 2019; Lara-Porras et al., 2019; Roth et al., 2015). These findings highlight the importance of culturally responsive teaching and differentiated assessments to ensure that all students have equitable opportunities to develop essential quantitative reasoning skills.

Finally, the integration of technology, particularly during the COVID-19 pandemic, showed mixed results. While some studies reported moderate gains in literacy through online platforms and LMS-supported environments, the effectiveness largely depended on instructional quality, student motivation, and teacher digital competence (Donmuş-Kaya & Kükey, 2022; Fauzi & Chano, 2022; Rahayu et al., 2021). These findings stress that technology, while valuable, must be embedded in thoughtful pedagogy to yield meaningful learning outcomes.

CONCLUSIONS, IMPLICATIONS, LIMITATIONS, AND FUTURE RESEARCH

This review shows the evolving role of mathematical literacy as a key educational outcome and as a necessary life skill. The findings demonstrate that while instructional innovations and cognitive support can improve students' mathematical literacy, significant challenges remain, particularly in areas of real-world problem formulation, equitable access, and teacher preparedness. As educational systems continue to shift from rote learning to applied understanding, it is important to align pedagogy, assessment, and professional development with the mixed demands of mathematical literacy in the 21st century.

Our findings point out the need for didactic responses that go beyond equitable access and move toward equity-oriented pedagogy and assessment. Teachers must be prepared not only to recognize these intersecting barriers but also to adapt instruction in ways that meaningfully support diverse learners. This includes the use of differentiated mathematical literacy tasks that are linguistically accessible, culturally relevant, and cognitively inclusive. For example, a real-life budgeting task could be adapted by varying reading complexity, providing visual scaffolds, or allowing students to use digital tools for computation and interpretation. Likewise, assessment rubrics aligned with frameworks like PISA can be modified to emphasize process and reasoning over correctness alone, enabling a broader spectrum of student competencies to be recognized.

To support these instructional goals, teacher education and professional development should prioritize task design skills and the use of inclusive classroom strategies. Moreover, students from marginalized backgrounds benefit from mathematical modeling tasks situated in meaningful social or personal contexts, such as interpreting transportation schedules, analyzing local climate data, or planning equitable school lunch distributions. These tasks strengthen mathematical competencies and also affirm students' lived experiences as valid contexts for learning.

Several limitations should be noted. First, this review was limited to English-language, peer-reviewed journal articles, which may have excluded relevant research in other languages or from grey literature. Second, while the review employed a comprehensive and systematic search strategy, three full-text articles could not be retrieved due to access restrictions. Finally, the inclusion period (2015-2024) may have overlooked earlier foundational studies on mathematical literacy.

Future studies should address underexplored mathematical domains such as calculus, measurement, and financial literacy, and extend research into higher education contexts, where mathematical literacy is still rarely assessed or integrated. There is also a need for more longitudinal studies tracking students' literacy development over time, as well as investigations into interventions about learners with disabilities and linguistic minorities.

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APPENDIX

Table A1. Articles used in the analysis

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Table A1 (Continued). Articles used in the analysis

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