

Systematic Literature Review: The Relationship Between Metacognition and Students' Mathematical Problem-Solving Ability

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ABSTRACT

Although numerous empirical studies have examined the relationship between metacognition and students' mathematical problem-solving ability, the available evidence remains fragmented. Previous review studies primarily synthesized literature published before 2020, generally treated metacognition as a single construct, and provided limited discussion of differences across educational levels as well as methodological and conceptual heterogeneity. To address these limitations, this study systematically synthesizes empirical evidence published between 2020 and 2026 using a Systematic Literature Review (SLR) following the PRISMA 2020 protocol. Twenty empirical studies retrieved from Scopus, Web of Science, Google Scholar, and Sinta-indexed journals met the inclusion criteria and were critically appraised using the Mixed Methods Appraisal Tool (MMAT) 2018. A narrative synthesis was conducted because of substantial heterogeneity among the included studies. Unlike previous reviews, this study synthesizes findings by considering differences in metacognitive dimensions, educational levels, methodological characteristics, and study quality. The findings indicate a consistent qualitative pattern of positive association between metacognition and mathematical problem-solving ability across the reviewed studies, rather than a statistically established relationship. Metacognitive regulation, particularly planning, monitoring, and evaluation, emerged as the dimensions most consistently associated with mathematical problem-solving ability, although the evaluation stage remained the most challenging across studies. The available evidence is predominantly derived from junior and senior secondary education, highlighting the need for further high-quality primary research at the elementary school level. These findings provide a more comprehensive understanding of the role of metacognition and support its explicit integration into mathematics instruction.

Kata kunci:

kemampuan pemecahan masalah
matematis; metakognisi; MMAT;
systematic literature review.

Meskipun banyak studi empiris telah mengkaji hubungan antara metakognisi dan kemampuan pemecahan masalah matematika siswa, bukti yang ada masih terfragmentasi. Studi tinjauan sebelumnya terutama menyintesis literatur yang diterbitkan sebelum tahun 2020, umumnya memperlakukan metakognisi sebagai satu konstruk tunggal, serta memberikan pembahasan terbatas mengenai perbedaan jenjang pendidikan dan heterogenitas metodologis maupun konseptual. Untuk mengatasi keterbatasan tersebut, penelitian ini secara sistematis menyintesis bukti empiris yang diterbitkan antara tahun 2020 dan 2026 menggunakan metode *Systematic Literature Review* (SLR) yang mengikuti protokol PRISMA 2020. Sebanyak dua puluh studi empiris yang diperoleh dari Scopus, Web of Science, Google Scholar, dan jurnal terindeks Sinta memenuhi kriteria inklusi dan dinilai secara kritis menggunakan *Mixed Methods Appraisal Tool* (MMAT) 2018. Sintesis naratif dilakukan karena adanya heterogenitas yang substansial di antara studi-studi yang disertakan. Berbeda dengan tinjauan sebelumnya, penelitian ini menyintesis temuan dengan mempertimbangkan perbedaan dalam dimensi metakognitif, jenjang pendidikan, karakteristik



metodologis, dan kualitas studi. Temuan menunjukkan adanya pola kualitatif yang konsisten mengenai hubungan positif antara metakognisi dan kemampuan pemecahan masalah matematika di seluruh studi yang ditinjau, alih-alih hubungan yang ditetapkan secara statistik. Regulasi metakognitif, khususnya perencanaan, pemantauan, dan evaluasi, muncul sebagai dimensi yang paling konsisten dikaitkan dengan kemampuan pemecahan masalah matematika, meskipun tahap evaluasi tetap menjadi bagian yang paling menantang di berbagai studi tersebut. Bukti yang tersedia sebagian besar berasal dari jenjang pendidikan menengah pertama dan menengah atas, sehingga menyoroti perlunya penelitian primer berkualitas tinggi lebih lanjut di tingkat sekolah dasar. Temuan ini memberikan pemahaman yang lebih komprehensif mengenai peran metakognisi dan mendukung integrasinya secara eksplisit ke dalam pembelajaran matematika.

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INTRODUCTION

Mathematics is a discipline that plays a fundamental role in modern human life (Kumar et al., 2025). In the 21st century, mathematical problem-solving ability has become a key competency that every individual should possess (OECD, 2023). Mathematical problem-solving is not merely a calculation skill; rather, it involves a series of high-level cognitive processes—analyzing situations, selecting strategies, implementing procedures, and evaluating the correctness of results (Polya, 1957). The effectiveness of these problem-solving stages has also been demonstrated in classroom-based studies, in which learning activities explicitly structured around Polya's framework significantly improved students' mathematical problem-solving ability (Amalia & Salafudin, 2022; Cahyani et al., 2024). According to the results of the 2022 *Programme for International Student Assessment* (PISA), Indonesia ranked 68th among 81 participating countries, with an average mathematics score of 366 points—down from 379 points in 2018 and well below the OECD average of 472 points (NCTM, 2000; OECD, 2023). Virtually no Indonesian students reached Level 5 or 6 on the PISA mathematics test—levels where students are capable of modeling complex situations and evaluating appropriate problem-solving strategies. This situation indicates that the mathematical problem-solving abilities of Indonesian students require serious attention.

Metacognition, a cognitive factor, has garnered increasing attention in contemporary mathematics education research (William & Maat, 2020). Flavell (1979) defined metacognition as knowledge of and cognition about cognitive phenomena. To avoid

conceptual conflation, three key terms must be explicitly distinguished in this study. First, metacognitive knowledge encompasses declarative knowledge (what is known), procedural knowledge (how to perform a task), and conditional knowledge (when and why to employ specific strategies) (Schraw & Dennison, 1994). Second, metacognitive regulation comprises three sequential skills: planning, monitoring, and evaluation (Brown, 1987). Third, metacognitive awareness refers to an individual's general awareness of their own thinking processes, which underlies both metacognitive knowledge and metacognitive regulation (Schraw, 1998). Metacognitive skills are strong predictors of learning achievement—surpassing even general intellectual ability alone (Veenman et al., 2006).

Despite the growing number of empirical studies and review articles examining metacognition in mathematics education, several important issues remain insufficiently addressed. Although previous studies consistently indicate that metacognition contributes to students' mathematical problem-solving ability, the available evidence remains fragmented. First, most review studies synthesized literature published before 2020 and therefore fail to capture the substantial increase in empirical research during the period 2020–2026 (Thi-Nga et al., 2024; William & Maat, 2020). Second, prior reviews have generally treated metacognition as a single construct without explicitly distinguishing among metacognitive knowledge, metacognitive regulation, and metacognitive awareness, even though these dimensions are conceptually different (Brown, 1987; Schraw & Dennison, 1994; Schraw, 1998). Third, variations across educational levels and methodological approaches have received limited attention, making it difficult to determine whether the reported findings are comparable across different learning contexts. Finally, the considerable heterogeneity in research designs, measurement instruments, and problem-solving frameworks has rarely been critically discussed, despite its potential influence on the interpretation of research findings. Moreover, recent studies in mathematics education have predominantly examined mathematical problem-solving from isolated perspectives, such as instructional interventions (Amalia & Salafudin, 2022), curriculum comparisons (Hidayati et al., 2025), the application of cognitive development theory to mathematical problem solving (Suyanto et al., 2026), or differences in students' metacognitive processes based on individual learning characteristics (Yanti & Alvira, 2026). Collectively, these studies provide valuable insights into specific aspects of mathematical problem solving. However, they remain fragmented in scope and do not systematically synthesize empirical evidence on how different dimensions of metacognition relate to mathematical problem-solving ability across educational levels.

Furthermore, variations in research design, metacognitive conceptualizations, measurement instruments, and problem-solving frameworks have not been comprehensively synthesized.

To address these gaps, this study presents a Systematic Literature Review (SLR) of empirical studies published between 2020 and 2026 concerning the relationship between metacognition and students' mathematical problem-solving ability. Unlike previous reviews, this study provides an updated synthesis of empirical evidence but also synthesizes findings by considering differences in metacognitive dimensions, educational levels, and methodological characteristics of the included studies. Furthermore, all included studies are critically appraised using the *Mixed Methods Appraisal Tool* (MMAT) 2018 to strengthen the methodological rigor of the review. Accordingly, this review provides a more comprehensive and up-to-date understanding of the relationship between metacognition and mathematical problem-solving ability while offering evidence-based implications for mathematics education research and practice. Based on these objectives, this review addresses the following research questions: (1) What is the relationship between metacognition and students' mathematical problem-solving ability? (2) Which dimensions of metacognition are most consistently associated with mathematical problem-solving ability? (3) How does this relationship vary across educational levels? and (4) What methodological and contextual factors explain similarities and differences among the reported findings?

METHOD

This study employed a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines (Page et al., 2021) and adopted a narrative synthesis approach (Popay et al., 2006). A narrative synthesis was adopted because of the substantial methodological heterogeneity among the included studies, which precluded a quantitative meta-analysis and the calculation of a pooled effect size. The review followed the four stages of the PRISMA 2020 framework: identification, screening, eligibility assessment, and inclusion.

Data Sources and Search Strategy

A literature search was conducted across four databases—(1) Scopus, (2) Web of Science, (3) Google Scholar, and (4) Sinta (Ministry of Education, Culture, Research, and Technology)—covering studies published between 2020 and 2026. The search strategy employed Boolean operators (AND/OR) with a comprehensive combination of keywords.

English: ("*metacognition*" OR "*metacognitive awareness*" OR "*metacognitive regulation*") AND ("*mathematical problem solving*" OR "*problem-solving ability*" OR "*mathematics learning*") AND ("*student*" OR "*elementary school*" OR "*junior high school*" OR "*senior high school*")

Indonesian: ("*metakognisi*" OR "*kesadaran metakognitif*" OR "*regulasi metakognitif*") AND ("*kemampuan pemecahan masalah matematis*" OR "*kemampuan pemecahan masalah matematika*" OR "*pembelajaran matematika*") AND ("*siswa sekolah dasar*" OR "*siswa SMP*" OR "*siswa SMA*")

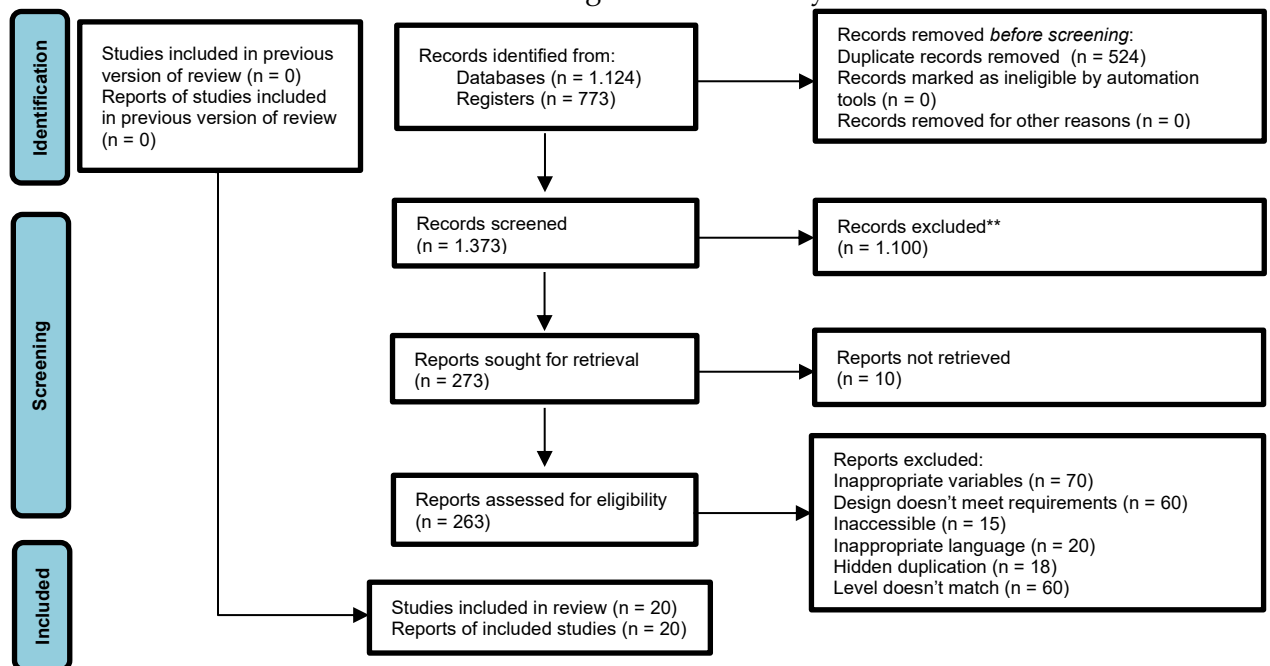
Inclusion and Exclusion Criteria

Inclusion criteria: (1) peer-reviewed journal articles indexed in Scopus, Web of Science, or Sinta 1-4; (2) published between 2020 and 2026 in Indonesian or English; (3) participants were elementary, junior high, or senior high school students; (4) examined both metacognition and students' mathematical problem-solving ability; (5) utilized qualitative, descriptive quantitative, mixed-methods, or research and development (R&D) research designs reporting empirical data on metacognition and mathematical problem-solving; (6) full text available via open access or institutional access.

Exclusion criteria: (1) conference proceedings, books, articles indexed in Sinta 5-6, theses, dissertations, technical reports, or non-empirical opinion pieces; (2) examined only one variable (metacognition alone or problem-solving alone); (3) subjects were not school students (elementary/junior high/senior high); (4) publication year outside the 2020 - 2026 range; (5) full-text articles that were inaccessible.

Study Selection Process (PRISMA 2020)

Study selection was conducted independently by two reviewers in two stages; disagreements were resolved through discussion. Stage one: title and abstract screening. Stage two: full-text eligibility assessment. The PRISMA selection flow is presented in Table 1.

Table 1. PRISMA 2020 Flow Diagram of The Study Selection Process

Study Quality Assessment

Methodological quality assessment was conducted using the *Mixed Methods Appraisal Tool* (MMAT) version 2018 (Hong et al., 2018), following the official MMAT 2018 user guide. The assessment involved a critical appraisal based on the empirical research design of each study, covering five design categories: (1) qualitative, (2) randomized controlled trials, (3) quantitative non-randomized, (4) quantitative descriptive, and (5) mixed methods. Each category comprises five specific assessment criteria answered as "Yes," "No," or "Can't tell," with the final score reported as the number of criteria met out of five (e.g., $\frac{4}{5}$). For qualitative designs, criteria included the appropriateness of the qualitative approach, adequacy of data collection methods, derivation of findings from data, adequacy of interpretation substantiation, and coherence across data sources. For quantitative descriptive designs, criteria included the relevance of the sampling strategy, sample representativeness, appropriateness of measurement instruments, risk of non-response bias, and appropriateness of statistical analysis. For mixed-methods designs, criteria included the clarity of the rationale for using a mixed-methods design, integration between components, adequacy of the interpretation of combined results, handling of divergent findings, and fulfillment of quality criteria for each respective tradition (qualitative and quantitative). Studies with an MMAT scores of $\leq \frac{2}{5}$ or lower were considered for exclusion to maintain the

quality of the synthesis; in the final corpus of this study, all 20 studies achieved MMAT scores of at least $\geq \frac{3}{5}$ (Table 2).

Data Extraction and Analysis

Data were extracted using a structured form covering bibliographic information, sample level and size, mathematical topic, metacognition measurement instruments, problem-solving indicators used, study quality score (MMAT), research design/method, conceptualization of metacognition, and key findings. Data extraction was conducted independently by the two reviewers to reduce the risk of individual interpretation bias and to improve the reliability of the extracted information. After independent extraction, the two reviewers compared their results and discussed any discrepancies. Disagreements were resolved through consensus between the reviewers. The extracted information also enabled the identification of methodological and conceptual heterogeneity across the included studies, particularly regarding: (1) metacognition measurement instruments; (2) research designs; (3) mathematical problem-solving indicators; and (4) conceptualizations of metacognition. These sources of heterogeneity were considered throughout the synthesis because they could influence the interpretation, comparability, and robustness of the synthesized evidence.

A narrative synthesis was conducted following the framework proposed by Popay et al. (2006) through four stages: (1) development of an initial theory regarding the mechanisms linking metacognition and mathematical problem-solving ability; (2) preliminary description of the studies and findings (tabulated in Table 2); (3) exploration of relationships within and across studies through thematic grouping; and (4) assessment of the robustness of the synthesis by considering methodological quality (MMAT scores), the identified sources of heterogeneity, and the balance of the number of studies across educational levels.

RESULTS AND DISCUSSION

Research Results

Following the PRISMA 2020 selection process, 20 studies were included in the final synthesis (Table 2). The distribution of educational levels revealed a clear predominance of the junior high school level ($n = 14$; 70%), followed by senior high school studies ($n = 5$; 25%) and one cross-level study ($n = 1$; 5%) conducted in the Finnish educational context (Toikka et al., 2024), which included students from grades 6 (the end of primary education in the Finnish system), 7, and 9. Notably, no study in the reviewed corpus explicitly investigated

Indonesian elementary school students; representation of the primary school level was obtained only partially and indirectly through the grade 6 subsample in the study (Toikka et al., 2024). This constitutes a significant limitation that will be discussed further in sections 3.2.3 and 4. Regarding research design, the qualitative descriptive approach was the most frequently used ($n = 13$; 65%), followed by mixed methods ($n = 6$; 30%) and quantitative descriptive designs ($n = 1$; 5%). The mathematical topics most frequently examined were algebra (including systems of linear equations with two variables and sequences/series) and geometry, reflecting a research trend toward topics that require both procedural and conceptual reasoning. All included studies achieved MMAT scores ranging from 3/5 to 5/5 across all 20 included studies (Table 2).

Table 2. Synthesis of Findings from 20 Studies: The Relationship Between Metacognition and Students' Mathematical Problem-Solving Ability

Researcher & Year	Level	Sample Size	Material	Metacognition Instrument	Problem-Solving Indicators	Study Quality Index (MMAT)	Method	Key Findings
(Subbata et al., 2025)	JHS	Phase 1: Linear 7 teachers + 3 experts (evaluation); Phase 2: 27 students (pilot, cluster by district)	Linear Relations and Equations	IOC-validated semi-structured interview; 5-point Likert scale (model evaluation); PM pre- and post-tests (4 questions); focus group interview.	6-stage integrated model combining Poly's stages and Schoenfeld's metacognitive framework	4/5	R&D + mixed-methods, 2 phase	The 6-stage constructivist model effectively enhances metacognition; expert feasibility rating of 4.33 (SD 0.70); Effectiveness Index = 0.51 (effective category).
(Permatadita et al., 2023)	SHS	18 students	Arithmetic sequences and series	Metacognitive ability essay test; Metacognitive Awareness Inventory (MAI) in the questionnaire (16 items)	Aspects of fluency and elaboration in the answers	4/5	Descriptive qualitative	The higher the level of metacognition, the better the learning creativity (fluency and elaboration) in solving sequence and series problems.
(Nurhayati & Kusair)	JHS	3 students (high, medium, low)	Geometry (Uma Lengge)	Essay test; interview; ethnomathematic observation;	Poly's stages: planning,	5/5	Qualitative descriptive	High metacognition is effective across

Researcher & Year	Level	Sample Size	Material	Metacognition Instrument	Problem-Solving Indicators	Study Quality Index (MMAT)	Method	Key Findings
i, 2024)		medium, low) out of 23 students	atics, Bima)	documentation (methodological triangulation)	monitoring , evaluation		e	all three stages; moderate levels involve errors in formula application; low levels result in failures to plan and monitor.
(Nurai ni et al., 2024)	JHS	6 students (3 extroverts, 3 introverts) out of 32 students	Pythagorean theorem	Personality type questionnaire (adapted from the Eysenck Personality Inventory); problem-solving test; interview (adapted from Kayashima)	Polya's 4 stages × 3 metacognitive processes (planning, monitoring , evaluation)	5/5	Qualitative case study	Extrovert: <i>tacit use</i> level (only the stage of fully understanding the problem); Introvert: <i>strategic use</i> level (excels in the first two stages).
(Safitri et al., 2020)	JHS	15 students (questionnaire) -> 3 purposive subjects	Contextual problems based on the PISA model	PISA-style test (9 items); MAI questionnaire adapted from Schraw & Dennison (1994), 38 statements.	Planning, Monitoring , Evaluation in 4 stages Polya	4/5	Descriptive qualitative	Metacognition very good/good -> problem-solving classified as moderate (weak evaluation); metacognition poor -> problem-solving classified as low.
(Suryaningtyas & Setyaningrum, 2020)	SHS	160 students from 6 schools (stratified random sampling)	Algebra (derivative)	Test; MAI questionnaire adapted from Schraw & Dennison (1994)	Categorization of metacognition usage as high, medium, or low	4/5	Quantitative & qualitative (mixed) survey	44% of students with high metacognition were able to use it when solving problems, whereas 46% of those with low metacognition hardly used it at all.
(Khasanah, 2021)	JHS	6 students (3 with high	Not specific (Adversity Quotient context)	AQ questionnaire; metacognitive questionnaire; problem-solving	Checking for sufficient information, seeking	4/5	Qualitative descriptive	Those with high metacognition demonstrate sufficient competence in

Researcher & Year	Level	Sample Size	Material	Metacognition Instrument	Problem-Solving Indicators	Study Quality Index (MMAT)	Method	Key Findings
		metacognition, 3 with medium metacognition), purposive		test; interview	alternatives, carrying out the solution, and verifying the correctness of the answer.			the final three indicators, while those with moderate metacognition demonstrate sufficient competence in two indicators.
(Taufik et al., 2022)	JHS	2 students	Algebra (System of Linear Equations with Two Variables)	Mathematics proficiency test; Matching Familiar Figure Test (cognitive style); problem-solving task + task-based interview.	Planning, monitoring, and evaluation	3/5	Qualitative descriptive	Reflective style - > <i>reflective use</i> level; impulsive style -> <i>aware use</i> level (weak at the evaluation stage)
(Pardiansyah et al., 2021)	SHS	Not specified (simple random sampling)	Set	Tests; interviews (instruments not detailed in full in the source)	Awareness, regulation, evaluation	3/5	Mixed method	Metacognition-based problem-solving ability is rated as good; the indicators of awareness, regulation, and evaluation have been mastered.
(Toikka et al., 2024)	Cross-level: late primary to junior high school (grade 6, 7, 9)	225 students (interview)	Not specific	Theory-based structured interviews; advanced quantitative analysis	Declarative - procedural - conditional framework ; contextual (person-task-strategy)	4/5	Mixed methods	Metacognitive knowledge varies across grade levels; 9th-grade students outperform 6th and 7th graders in the conditional aspect.
(Khunien et al., 2024)	JHS	6 students (2 high, 2 medium, 2 low)	Statistics	Not fully detailed in the source (problem-solving test + metacognition categorization)	The source does not provide a breakdown by stage.	3/5	Mixed method sequential explanatory	Google Classroom-assisted PBL is effective; the experimental group's classical mastery

Researcher & Year	Level	Sample Size	Material	Metacognition Instrument	Problem-Solving Indicators	Study Quality Index (MMAT)	Method	Key Findings
		from the experimental and control groups						exceeded 75%, which was higher than that of the control group.
(Saodah et al., 2024)	JHS	Not specified (experimental-control group)	Open-ended questions (general)	Not fully detailed in the source (problem-solving test + metacognition categorization)	Formulating the problem, selecting a strategy, implementing the strategy, interpreting the results.	3/5	Mixed method - concurrent mixed methods	Sevima Edlink-assisted open-ended PBL is effective; students with high metacognition perform optimally across four indicators but struggle to interpret results.
(Defit et al., 2022)	JHS	28 students (one whole class)	Non-specific (regarding general problem-solving)	Metacognitive level test; interview (Laurens's leveling framework, 2010)	Metacognition level: <i>strategic use, aware use, tacit use</i>	3/5	Qualitative descriptive	35.71% of students demonstrated <i>tacit use</i> , 35.71% <i>aware use</i> , and 28.58% <i>strategic use</i> ; high-ability group -> <i>strategic use</i> , medium -> <i>aware use</i> , low -> <i>tacit use</i> .
(Murtiyasa & Anggraini, 2022)	JHS	65 students	Not specific	Test; documentation	Pólya's Stages	4/5	Qualitative descriptive	High metacognition: 14%; medium: 51%; low: 35%; students with low metacognition failed to plan and double-check.
(Prastiti et al., 2026)	JHS	12 students (out of 33, purposive)	Non-routine linear equations (System of linear	Mathematics proficiency test; collaborative PM task; classroom observation;	Planning, monitoring, evaluating	5/5	Qualitative case study	Planning and monitoring consistently appear in heterogeneous

Researcher & Year	Level	Sample Size	Material	Metacognition Instrument	Problem-Solving Indicators	Study Quality Index (MMAT)	Method	Key Findings
		ve samplin g) in 4 heterog eneous groups	equations in two variables)	video recordings; semi-structured group interviews.				groups; metacognitive evaluation is less developed and unevenly distributed.
(Surya ni et al., 2023)	JHS	6 student s (2 high, 2 mediu m, 2 low)	Not specific	Mathematics Ability Test (TKM); Problem-Solving Test (TPM); interview guidelines	Metacognit ion level: <i>strategic use, aware use, tacit use</i>	4/5	Qualitativ e descriptiv e	High mathematical ability -> <i>strategic use</i> ; moderate -> <i>aware use</i> ; low -> <i>tacit use</i> (linear correspondence)
(Kurni awan & Wijaya nti, 2022)	SHS	3 student s (1 high, 1 mediu m, 1 low)	Composition Functions and Inverse Functions	Problem-solving test; interview	Understan ding the problem, awareness of the steps taken, and review.	3/5	Qualitativ e descriptiv e	Metacognitive profiles are similar across the three proficiency levels; low-proficiency students do not engage in review (evaluation).
(Shodi kin et al., 2022)	JHS	3 siswa (tinggi, sedang, rendah)	Set	Problem-solving test; interview	Metacognit ion level: <i>strategic use, aware use, tacit use</i>	3/5	Qualitativ e descriptiv e	Problem-solving level: high -> <i>reflective use</i> ; medium -> <i>strategic use</i> ; low -> <i>aware use</i> .
(Wang guway et al., 2025)	SHS	Not specifie d	Contextual mathematics problems (general)	Various test instruments; interview guidelines; triangulation	Awareness, evaluation, regulation	3/5	Qualitativ e descriptiv e	Awareness arises when considering prior knowledge; evaluation, when assessing methods; and regulation, when considering actions.
(Fadilla h et al., 2021)	JHS	Not specifie d (case study)	Geometry	Not fully detailed in the source (regarding self-efficacy	Knowledge of cognition; regulation	3/5	Qualitativ e case study	High self-efficacy enables the fulfillment of all components

Research & Year	Level	Sample Size	Material	Metacognition Instrument	Problem- Solving Indicators	Study Quality Index (MMAT)	Method	Key Findings
				measurement + problem-solving test)	of cognition			of metacognition (knowledge and regulation of cognition).

Discussion

Consistent Qualitative Patterns of Association between Metacognition and Problem-Solving Ability

The principal finding of this Systematic Literature Review (SLR) is a consistent qualitative pattern indicating a positive association between metacognition and mathematical problem-solving ability across the reviewed studies. This pattern was observed across different educational levels, cultural contexts, research designs, and mathematical content. However, the finding should not be interpreted as evidence of a statistically established or causal relationship. Most of the included studies employed qualitative descriptive designs (13 of 20 studies; 65%), while only a small proportion employed quantitative descriptive methods. Therefore, the present synthesis identifies recurring qualitative patterns in which higher or more developed metacognitive processes tend to be accompanied by better mathematical problem-solving performance, rather than demonstrating a statistically significant association across the entire corpus.

This qualitative pattern is broadly consistent with Schoenfeld's theoretical framework, which posits that metacognitive control is one of four key determinants of successful mathematical problem-solving ability, alongside mathematical knowledge. Schoenfeld's framework emphasizes that competent problem solvers actively monitor their progress and adjust or change strategies when their current approach is ineffective, reflecting the role of metacognitive regulation in problem solving (Schoenfeld, 2016). Several studies in the present corpus illustrate similar patterns. Pardiansyah et al. (2021), for example, reported that students demonstrating stronger metacognitive awareness, regulation, and evaluation also showed stronger problem-solving performance in set problems. Similarly, Wangguway et al., (2025) documented the occurrence of metacognitive activities involving awareness, evaluation, and regulation during contextual mathematical problem solving.

The observed qualitative pattern is also compatible with findings from Hidayat et al., (2025), whose meta-analysis of 43 studies involving 13,924 participants reported a large

overall effect size ($ES = 1.11$) for metacognitive instruction on mathematics achievement. Although that meta-analysis was not part of the present SLR corpus and examined instructional effects rather than the same research question, it provides complementary quantitative evidence that supports the plausibility of an association between metacognition and mathematical learning outcomes. Nevertheless, its findings should be regarded as supporting evidence from the broader literature rather than as statistical confirmation of the qualitative synthesis presented in this review.

Correspondence Between Metacognitive Levels and Problem-Solving Quality

The second finding concerns the relatively consistent correspondence between students' metacognitive levels and the quality of their mathematical problem-solving. Several studies in this corpus employ the metacognitive level framework comprising *tacit use*, *aware use*, *strategic use*, and *reflective use* (utilized, for instance, by Shodikin et al., (2022)) to categorize the quality of students' metacognitive application.

First, students with high metacognition (at the *reflective use* or *strategic use* levels) consistently fulfilled most or all problem-solving indicators. Suryani et al., (2023) identified a linear correspondence: high mathematical ability corresponds to the *strategic use* level; moderate ability to *aware use*; and low ability to *tacit use*. Shodikin et al., (2022) observed a similar pattern regarding the topic of sets. Nurhayati & Kusaeri, (2024) found consistent results within the context of ethnomathematics-based geometry, noting that students with high metacognition were able to plan, monitor, and evaluate effectively.

Second, students with moderate metacognition (at the *aware use* level) tend to fulfill some problem-solving indicators but encounter obstacles, particularly during the evaluation and result-interpretation stages. Saodah et al., (2024) found that students with moderate metacognition struggled with the indicator of interpreting problem-solving results, even though they were relatively proficient in selecting strategies.

Third, students with low metacognition (at the *tacit use* level) tend to face difficulties from the initial stages of problem-solving—specifically in understanding the problem—and fail to plan or review their solution steps. Murtiyasa & Anggraini, (2022) found that 35% of the junior high school students in their study fell into this category. This three-level pattern was also confirmed by Defi et al. (2022) among ninth-grade junior high school students in Padang: the high-mathematical-ability group consistently fell into the *strategic use* level (28.58% of students), the medium group into the *aware use* level (35.71%), and the low group into the *tacit use* level (35.71%), mirroring the linear correspondence pattern also observed by

Suryani et al. (2023) and Shodikin et al. (2022) using the same leveling framework. This three-level pattern aligns with Polya (1957) problem-solving stages: the problem-understanding stage relies on metacognitive awareness; the planning stage relies on metacognitive planning; the execution stage relies on metacognitive monitoring; and the looking-back stage represents the most explicit form of metacognitive evaluation. Within this corpus, the looking-back stage consistently emerges as the stage least optimally fulfilled – as seen, for instance, in the findings of Murtiyasa & Anggraini, (2022) and Kurniawan & Wijayanti, (2022) – indicating that metacognitive evaluation is generally the most challenging component for students across the studies in this SLR corpus.

Variations in Metacognitive Patterns Across Educational Levels: A Note of Caution

This interpretation of educational-level differences requires particular caution because of the uneven distribution of studies across educational levels. As noted in Research Result, the corpus of this Systematic Literature Review (SLR) does not include primary studies directly examining elementary school (SD) students in Indonesia. No study directly investigated Indonesian elementary school students. Therefore, conclusions regarding this educational level should be interpreted cautiously.

Consequently, the discussion regarding variations in metacognitive patterns across educational levels in this SLR is limited to a comparison between junior high (SMP) and senior high (SMA) levels, with one additional note from the cross-level study by Toikka et al., (2024), which offers some indirect indication regarding potential patterns at the late elementary stage (6th grade in the Finnish system).

At the junior high level – which dominates this SLR corpus (accounting for 70% of the studies) – several studies found that students already demonstrate basic planning and monitoring capabilities but tend to be weak in the evaluation (reviewing) stage. Taufik et al. (2022) found that students with an impulsive cognitive style were unable to verify the correctness of their answers – an indication of evaluative weakness. Prastiti et al., (2026) found that in heterogeneous collaborative settings, metacognitive evaluation was underdeveloped and unevenly distributed among group members.

At the senior high level, the challenge appears to shift toward a more complex dimension: conditional knowledge – specifically, knowing when and why to employ certain strategies flexibly. Suryaningtyas & Setyaningrum, (2020) found that 46% of the science-track senior high school students in their study possessed low metacognitive ability and barely utilized metacognition when solving advanced algebra problems (involving derivatives).

Kurniawan & Wijayanti, (2022) found that the primary difference between high- and low-achieving high school students lies in their ability to review their work. As a related insight from outside the Indonesian context, Toikka et al., (2024) found that 9th-grade students (equivalent to the end of junior high school in Finland) outperformed 6th- and 7th-grade students in conditional knowledge; this finding is tentatively consistent with the notion that conditional knowledge matures with age and learning experience.

Due to the limited number and scope of studies – particularly the absence of primary school research directly relevant to the Indonesian context – no definitive generalizations regarding a universal "pattern of tiered deficits" can be drawn from this body of work. The observed patterns (evaluation posing a general challenge at the junior high level, while conditional knowledge presents a more pronounced challenge at the high school level) should be viewed as preliminary hypotheses requiring further validation through primary research – especially at the primary school level – before they can be generalized.

Contextual Factors Potentially Influencing the Link Between Metacognition and Problem Solving

This systematic literature review (SLR) identifies several contextual factors that appear to influence the strength and pattern of the relationship between metacognition and mathematical problem-solving ability. The term "contextual factor" is used instead of "moderator" because, methodologically, a moderator implies formal statistical testing (e.g., via interaction analysis or meta-regression) – procedures not performed in the majority of qualitative studies within this corpus.

First, prior mathematical ability. Suryani et al. (2023) and Shodikin et al. (2022) found that students' levels of prior mathematical ability corresponded to the levels of metacognition they demonstrated. This aligns with Schoenfeld's model, which positions mathematical knowledge ("resources") and metacognitive control as interacting components rather than isolated elements (Schoenfeld, 2016).

Second, cognitive style and personality type. Taufik et al., (2022) found that students with a reflective cognitive style tended to reach higher levels of metacognition (*reflective use*) compared to impulsive students (*aware use*). Nuraini et al., (2024) found that, in their study on geometry (the Pythagorean Theorem), introverted students excelled in metacognitive usage (*strategic use*) compared to extroverted students (*tacit use*). It should be noted that these findings are context-specific, based on small samples (three students per group), and cannot

be generalized to establish a causal relationship between personality type and metacognitive ability.

Third, learning models and settings. Khunaeni et al., (2024) found that the implementation of Problem-Based Learning assisted by Google Classroom was associated with higher rates of class mastery in the experimental group compared to the control group. Prastiti et al., (2026) found that heterogeneous collaborative settings facilitate the distribution of metacognitive functions, with high-ability students acting as metacognitive triggers for other group members – although this effect was not uniform across all members. Subba et al., (2025) added that a constructivist-based learning model incorporating scaffolding and explicit self-monitoring elements demonstrated effectiveness in their pilot test (Effectiveness Index = 0.51).

In addition to the contextual factors discussed above, the findings of this review should also be interpreted in light of the substantial methodological and conceptual heterogeneity observed across the included studies. The reviewed articles differed in the metacognition measurement instruments employed, research designs, mathematical problem-solving indicators, and conceptualizations of metacognition. Such variations may partially explain differences in the reported strength and characteristics of the relationship between metacognition and mathematical problem-solving ability across studies. For example, studies using standardized instruments such as the Metacognitive Awareness Inventory (MAI) generally assessed metacognition as a multidimensional construct, whereas studies employing researcher-developed instruments often focused on specific aspects of metacognitive behaviour. Likewise, qualitative studies provided rich descriptions of students' metacognitive processes, while quantitative studies primarily examined statistical relationships between variables. Variations were also evident in the mathematical problem-solving frameworks adopted and in the theoretical perspectives used to conceptualize metacognition. Accordingly, direct comparisons among individual studies should be interpreted with caution. Nevertheless, despite these methodological and conceptual differences, the overall evidence consistently supports a positive relationship between metacognition and mathematical problem-solving ability across diverse educational contexts, indicating that the synthesized findings remain robust.

The Role of Self-Efficacy as a Reinforcing Factor

Fadillah et al., (2021) introduced a relevant affective dimension: in their study, mathematical self-efficacy was associated with the completeness of metacognitive

components employed by students during geometry problem-solving; specifically, students with high self-efficacy were able to satisfy all indicators regarding knowledge of cognition and the regulation of cognition. These findings align with Bandura's self-efficacy theory (Bandura, 1997) and the classic research (Pajares & Miller, 1994), which demonstrated—through path analysis—the predictive role of mathematical self-belief in mathematical problem-solving ability. The interplay between metacognition, memory workload, and mathematics anxiety is also illustrated by the RAMPS (Regulated Attention in Mathematical Problem Solving) framework developed by Scheibe et al., (2023); this framework posits that metacognitive experiences interact with working memory and mathematics anxiety to determine the quality of problem-solving.

The implication of these findings is that interventions targeting only the cognitive components of metacognition—without addressing students' mathematical self-belief—may yield more limited results. Instructional designs that simultaneously foster both metacognition and self-efficacy are likely to have a more comprehensive impact on mathematical problem-solving ability; however, this projection requires further empirical validation, as it is currently supported by only a single primary study within this body of research.

Theoretical and Practical Implications

Theoretically, the findings of this systematic literature review (SLR) reinforce the relevance of the frameworks proposed by Polya (1957) and Schoenfeld (2016) within the context of contemporary mathematics education in Indonesia. Simultaneously, they underscore the importance of conceptually distinguishing between metacognitive knowledge, metacognitive regulation, and metacognitive awareness (Brown, 1987; Schraw, 1998; Schraw & Dennison, 1994) when interpreting findings from studies that employ diverse instruments and terminology.

Practically, these findings entail three key implications. First, mathematics instruction should explicitly integrate elements that foster metacognition through the scaffolding of metacognitive questions (e.g., "What do you know?", "What is your plan?", "Does your answer make sense?"), structured reflection sheets, and collaborative discussions. Second, given that the evaluation or "looking back" phase consistently emerges as a weak point across many studies in this corpus, problem-solving assessment instruments need to be expanded to explicitly evaluate students' habits of reviewing and interpreting results, rather than focusing solely on the final answer. Third, in light of the absence of primary evidence

regarding the elementary school level, teacher training programs and the Indonesian mathematics education research agenda should prioritize the study of metacognition at the elementary school level.

CONCLUSION

Summary

This systematic literature review synthesizes evidence from 20 empirical studies published between 2020 and 2026 to provide a comprehensive and up-to-date understanding of the association between metacognition and students' mathematical problem-solving ability. The synthesis indicates a consistent qualitative pattern in which stronger or more developed metacognitive processes tend to be accompanied by better mathematical problem-solving performance across the reviewed studies. This finding should be interpreted as a qualitative association rather than a statistically established relationship, given that most included studies employed qualitative descriptive designs. Among the dimensions of metacognition, metacognitive regulation, particularly planning, monitoring, and evaluation, was the dimension most consistently associated with students' mathematical problem-solving ability, while metacognitive knowledge and awareness served as important foundations for effective cognitive regulation. Across educational levels, the available evidence was concentrated primarily at the junior and senior secondary school levels, whereas evidence from elementary education remained scarce, limiting robust conclusions for that educational level. The review further identified substantial methodological and conceptual heterogeneity in research designs, measurement instruments, problem-solving frameworks, and conceptualizations of metacognition, highlighting the need for greater methodological consistency in future research. Overall, this review contributes to the mathematics education literature by providing a more comprehensive, up-to-date, and methodologically rigorous synthesis of empirical evidence while highlighting recurring qualitative patterns linking metacognition with mathematical problem-solving.

Recommendations

Future research should prioritize primary studies examining metacognition and mathematical problem-solving among elementary school students in Indonesia, given the limited evidence identified in the present review. Longitudinal studies tracking the development of metacognition across educational levels are also needed to better understand

developmental changes over time. In addition, randomized controlled trials evaluating metacognitive interventions within the context of the *Kurikulum Merdeka* are needed to strengthen the evidence regarding instructional effectiveness. Finally, future studies should focus on developing and validating standardized instruments for measuring metacognition in the Indonesian mathematics education context to improve methodological consistency and facilitate comparisons across studies.

Declarations

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Interest

Generative AI : No Generative AI Used:

Statement No generative artificial intelligence (AI) tools were employed in any aspect of this research or the preparation of the manuscript.

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