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Realistic mathematics education and mathematical creative thinking: a systematic review

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Abstract

Mathematical Creative Thinking (MCT) is an important competency in mathematics education, yet evidence concerning its relationship with Realistic Mathematics Education (RME) remains methodologically diverse. Following PRISMA 2020, searches of Scopus, ERIC, DOAJ, and Crossref for studies published between 2020 and 2026 retrieved 1,228 records. Of these, 221 records were retained for bibliometric mapping, and nine primary studies met the criteria for in-depth synthesis. Methodological quality was appraised using the Mixed Methods Appraisal Tool (MMAT). Fluency and flexibility were assessed or reported in all nine studies (100%), originality in eight (88.9%), and elaboration in seven (77.8%). These percentages describe the frequency of indicator reporting, not improvements in student performance or differences in intervention effectiveness. Quantitative studies generally reported favorable MCT-related outcomes associated with RME, while qualitative studies described aspects of students' mathematical thinking. Differences in study design, measurement, and statistical reporting limit causal inference and comparisons across indicators. Future research should assess all four indicators consistently and report indicator-specific effect estimates.

Keywords: Bibliometric Analysis; Mathematical Creative Thinking; Quality Assessment; Realistic Mathematics Education; Systematic Literature Review.

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INTRODUCTION

Mathematical Creative Thinking (MCT) is a crucial competency in 21st-century mathematics education, necessitating a shift in the learning paradigm from rote memorization to the development of Higher-Order Thinking Skills (HOTS) (Kosasih et al., 2022; Zhu et al., 2025). MCT is characterized by the aspects of fluency, flexibility, originality, and elaboration (Çilingir Altiner, 2026; Kholid et al., 2024; Suherman & Vidákovich, 2022), it is not merely an innate talent but a dynamic skill that can be cultivated through innovative teaching methods. This ability is essential for students to generate diverse or novel strategies for solving mathematical problems (Rahmatin et al., 2025; Suherman & Vidákovich, 2024), making it a key benchmark for evaluating contemporary learning frameworks.

RME effectively bridges the gap between abstract mathematical concepts and real-life experiences while fostering a collaborative learning environment (Henry-Burrell, 2020; Mardia et al., 2025; Zulkardi et al., 2025). By applying the principle of "guided reinvention," RME encourages students to explore unconventional problem-solving pathways (da Conceicao Freitas et al., 2025; Khasanah & Siswono, 2025; Laurens et al., 2017), thereby enhancing their mathematical communication skills, reasoning abilities, and overall motivation (Alim et al., 2024; Paroqi et al., 2020; Purnamatati et al., 2023). This pedagogical shift aligns with the need to cultivate MCT skills as students engage in designing various mathematical models and problem-solving strategies.

Previous studies have reported favorable creative-thinking outcomes associated with RME (Farida et al., 2025; Ismunandar, 2020; Ndiung, 2021; Nisa et al., 2023), yet prior reviews addressing this relationship each carry limitations that constrain the depth of their conclusions. Iskandar & Juandi (2022) narratively reviewed only 11 studies (2011–2021) without a PRISMA protocol, quality appraisal, or indicator-level disaggregation, concluding merely that RME "positively influences" creative thinking. A meta-analysis by Juandi et al. (2022) covering 38 studies from ERIC, Sage, Springer, Semantic Scholar, and Google Scholar, as well as the study by Akosah et al. (2026) quantify RME's effect on general mathematical ability or achievement but do not isolate creative thinking or its four indicators, while Suherman & Vidákovich (2022) systematically reviewed 70 articles on MCT assessment without examining RME as a predictor. The reviews discussed above do not combine a PRISMA-guided synthesis of RME-MCT primary studies, formal methodological quality appraisal (MMAT), indicator-level disaggregation, and an up-to-date, multi-database bibliometric mapping, the integrated approach this review offers.

The integration of modern technology, particularly Artificial Intelligence (AI), into RME offers promising opportunities to enhance students' creative thinking skills. Current literature indicates that while small-scale experimental designs often fail to capture the full complexity of diverse responses within RME, the use of AI as a learning tool has the potential to overcome these limitations by acting as a "thinking partner" for students (Foster, 2026; Hibi, 2026; Ma et al., 2026; Singh, 2026). Integrating RME with technology or AI can optimize the process of vertical mathematization (Noverica & Simanjuntak, 2026), thereby fostering a deeper understanding and application of mathematical concepts (Susilwati et al., 2025). Recent research demonstrates that combining AI with a contextual approach enhances engagement and learning effectiveness (Noverica & Simanjuntak, 2026), however, long-term studies

comprehensively examining the effectiveness of this combination remain very limited. This scarcity, compounded by the methodological limitations of prior RME-MCT syntheses discussed above, underscores the need for a review capable of both rigorously consolidating existing empirical evidence and mapping where emerging combinations—such as AI-supported RME—currently sit within the broader research landscape.

This study aims to synthesize empirical evidence concerning the relationship between RME and students' MCT. By examining a selected corpus of primary studies from 2020 to 2026, this article seeks to bridge the gap between theoretical promise and empirical reality, while offering a descriptive account of reported MCT indicators, study characteristics, and methodological limitations. To achieve this objective, the following research questions will be addressed:

RQ1. What mathematical creative thinking outcomes are reported in studies examining RME-based instruction?

RQ2. How are the four indicators of mathematical creative thinking assessed or reported across the included studies?

RQ3. What learner-related factors and instructional features are examined alongside RME and mathematical creative thinking?

RQ4. What research gaps remain regarding the application of RME to foster mathematical creative thinking?

METHOD

Literature Search Strategy and Database Coverage

This systematic review followed the PRISMA 2020 guidelines (Page et al., 2021). The literature search was conducted on August 10, 2026, using four complementary scholarly information sources: Scopus, ERIC, DOAJ, and Crossref. Scopus was selected for its broad multidisciplinary coverage, while ERIC provided specialized coverage of educational research. DOAJ was included to identify peer-reviewed open-access journals, whereas Crossref served as a supplementary metadata-based discovery source rather than a curated bibliographic database. Searches targeted empirical studies published between 2020 and 2026 in English or Indonesian with English abstracts, including peer-reviewed journal articles and conference proceedings. Retrieved records were consolidated and duplicates removed before screening. The principal search terms, source coverage, retrieval date, and eligibility limits are described below; complete source-specific query exports are required for independent replication.

The search strategy used free-text terms organized into two concept groups: RME and MCT. Synonymous terms within each concept were combined with OR, while the two concept groups were connected with AND: ("Realistic Mathematics Education" OR "Realistic Mathematics Approach" OR RME OR "Pendidikan Matematika Realistik") AND ("mathematical creative thinking" OR "creative thinking in mathematics" OR "mathematical creativity" OR "creative mathematical thinking"). The search syntax was adapted to the functionality of each source and, where supported, applied to titles, abstracts, and keywords. Searches were restricted to publications from 2020 to 2026, and all retrieved records were merged and deduplicated before screening.

Eligibility Criteria and Screening Process

Studies were eligible for the in-depth synthesis if they (1) reported original empirical research examining RME in relation to MCT; (2) were published in peer-reviewed journals or conference proceedings between 2020 and 2026; (3) involved students at the K–12 or higher education level; (4) were available in full text; and (5) were written in English or Indonesian, with an English abstract. RME was operationally identified through the reported use of meaningful mathematical contexts and at least one identifiable RME-related instructional principle, such as guided reinvention, progressive mathematization, or the development of mathematical models. MCT was identified through explicit assessment or qualitative analysis of MCT, including one or more indicators of fluency, flexibility, originality, and elaboration. Eligible designs included experimental and quasi-experimental studies, qualitative studies, design research, and research-and-development studies with relevant empirical components. The individual study served as the primary unit of analysis. Comparison groups were not mandatory, allowing the inclusion of qualitative and design-oriented studies that examined MCT within RME-based learning.

The search identified 1,228 records from Scopus (n = 178), ERIC (n = 49), Crossref (n = 837), and DOAJ (n = 164). After removing 27 duplicates, 1,201 records underwent title-and-abstract screening. Of these, 221 records were retained for full-text assessment and bibliometric mapping. Following the exclusion of 212 records that did not meet the criteria for the in-depth RME–MCT synthesis, nine primary studies were included (Figure 1).

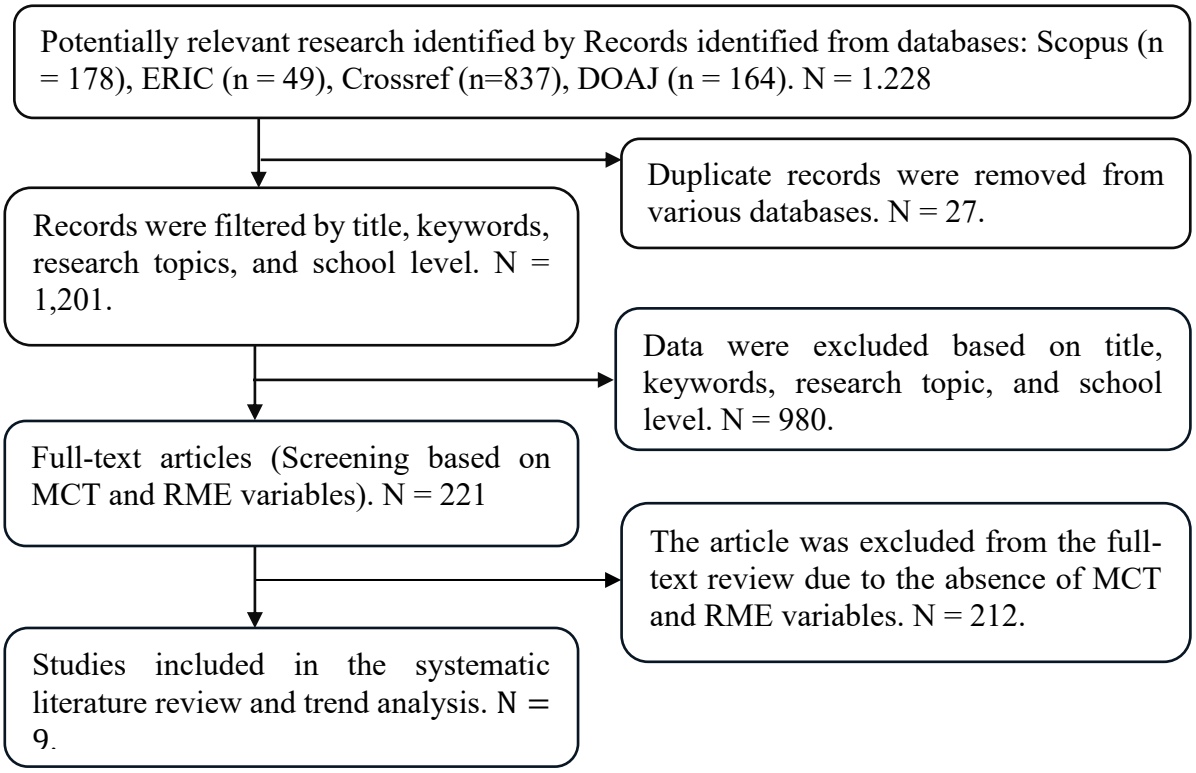


Figure 1. Stages of the systematic review

Following duplicate removal, 1,201 records were screened based on titles and abstracts. The screening process was conducted independently by two reviewers using the predefined eligibility criteria. Potentially relevant records were subsequently assessed at the full-text stage. Disagreements between the reviewers were resolved through discussion and consensus; when consensus could not be reached, a third reviewer was consulted. A total of 221 full-text articles were assessed for eligibility, of which 212 were excluded because they did not meet one or more eligibility criteria, including mismatch with the review topic, population, RME intervention, MCT outcomes, study design, publication type, or full-text requirements. Ultimately, nine primary studies met the eligibility criteria and were included in the qualitative synthesis.

Quality Assessment Framework

Methodological quality was appraised using the Mixed Methods Appraisal Tool (MMAT, 2018 version; Hong et al., 2018) applying the five design-specific criteria rather than treating C1–C5 as identical across designs. For quantitative non-randomized evaluations (A–F), C1–C5 correspond to MMAT 3.1 representativeness, 3.2 appropriateness of outcome and intervention measurements, 3.3 completeness of outcome data, 3.4 accounting for confounders, and 3.5 intervention delivery as intended. For qualitative investigations (G–I), C1–C5 correspond to

MMAT 1.1 appropriateness of approach, 1.2 adequacy of data collection, 1.3 derivation of findings from data, 1.4 substantiation of interpretations by data, and 1.5 coherence across data sources, collection, analysis, and interpretation. The assessment was conducted at the level of the empirical component contributing to the synthesis; Y, N and CT denote Yes, No and Cannot tell, respectively. Ratings are reported individually without a composite quality score.

The R&D–ADDIE investigation by Ramadhani et al. (2026) combined media development and validation with a 32-versus-32 student intervention comparison. Only the comparative outcome evaluation was eligible for the MMAT non-randomized category; expert validation and product-development activities were not assessed as independent effectiveness studies. Erwin & Julie (2025) described design research but reported interviews, student work, triangulation and qualitative data reduction and interpretation; the qualitative MMAT category therefore addresses this interpretive evidence, not the development cycle as a whole. Development and evaluation components were distinguished conceptually but were not scored as separate studies. The ratings in Table 1 are provisional pending criterion-by-criterion verification against the nine primary reports; the presence of a method or instrument alone does not establish methodological adequacy.

Table 1. Study-Level Methodological Quality Appraisal Using MMAT (2018)

Study	Reported design	MMAT category applied	C1	C2	C3	C4	C5	Code
Ramadhani et al. (2026)	R&D–ADDIE with experimental evaluation	Non-randomized study*	CT	Y	CT	N	Y	A
Nisa et al. (2023)	Quasi-experimental	Non-randomized study	CT	Y	CT	CT	Y	B
Hurulean & Miliyawati (2024)	Quasi-experimental	Non-randomized study	CT	Y	Y	Y	Y	C
Halim et al. (2020)	Quasi-experimental	Non-randomized study	CT	Y	Y	Y	Y	D
Hasibuan et al. (2024)	Quasi-experimental	Non-randomized study	CT	Y	Y	CT	Y	E
Ramadhanta et al. (2024)	Quasi-experimental, non-equivalent control group	Non-randomized study	CT	Y	Y	CT	Y	F
Erwin & Julie (2025)	Design research	Qualitative study*	Y	Y	Y	Y	Y	G
Tania et al. (2024)	Qualitative descriptive	Qualitative study	Y	Y	Y	Y	Y	H

Study	Reported design	MMAT category applied	C1	C2	C3	C4	C5	Code
Kusmaryono & Maharani (2021)	Qualitative classroom report	Qualitative study	Y	Y	Y	Y	Y	I

Note. Y = Yes; N = No; CT = Cannot tell. C1–C5 map to MMAT 3.1–3.5 for non-randomized studies (A–F) and MMAT 1.1–1.5 for qualitative studies (G–I). Ratings reproduced from the initial appraisal require criterion-level verification against the primary studies before submission. R&D development/validation and design-research development cycles were not independently scored.

Table 1 reports criterion-specific judgments rather than an overall methodological-quality grade. Non-randomized comparisons require particular caution regarding sample representativeness, missing outcome data, and confounding, while favorable qualitative judgments must be supported by identifiable data collection and analytic procedures. As some source reports do not clearly document all required safeguards, no conclusion of "generally adequate" quality is warranted from the coded ratings alone. Accordingly, Table 1 is presented as a provisional appraisal and is not used to rank studies or establish causal certainty.

Bibliometric Analysis Procedures

To map the intellectual structure and thematic clusters in the field, a keyword co-occurrence analysis was performed using VOSviewer (version 1.6.20) on the 221 full-text screened records. The unit of analysis was set to All Keywords, and the full counting method was applied. Prior to mapping, a thesaurus file was created to improve terminological consistency by merging synonymous terms (e.g., "RME," "realistic mathematics education," and "*Pendidikan Matematika Realistik*"), standardizing singular and plural forms (e.g., "indicator" and "indicators"), and removing generic or non-informative database descriptors. A minimum occurrence threshold of five occurrences was applied, resulting in 42 keywords eligible for network mapping. The clustering analysis was conducted using the default VOSviewer clustering settings (resolution parameter = 1.00; minimum cluster size = 1), resulting in three thematic clusters. Cluster themes were subsequently interpreted based on the dominant and conceptually related keywords within each cluster. The keyword harmonization procedure is described here; the underlying thesaurus should be archived with the review materials for reproducibility.

RESULTS AND DISCUSSION

Bibliometric Analysis

Keyword co-occurrence analysis was conducted on the 221 full-text records retained after title and abstract screening, consistent with the bibliometric corpus defined in the Methods

section. The initial 1,228 records represent the total records retrieved from the four information sources before deduplication and screening and were therefore not used directly for the VOSviewer mapping. Using the predefined threshold of at least five keyword occurrences, 42 keywords were included in the co-occurrence network. Figure 2 presents the resulting network visualization and its three keyword clusters.

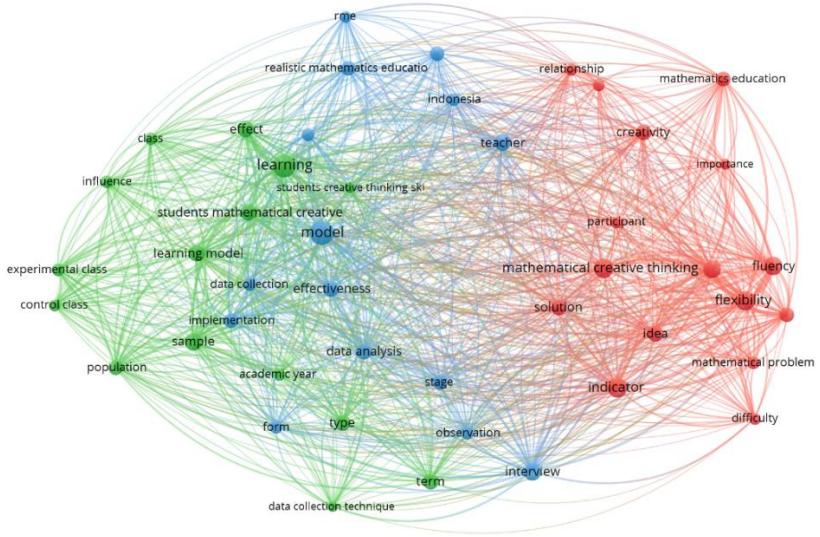


Figure 2. Network visualization

Figure 2 shows three keyword clusters generated by the VOSviewer co-occurrence analysis. Cluster labels were assigned retrospectively for interpretive purposes based on the most prominent and conceptually related keywords grouped within each cluster; the labels were not predefined analytical categories. The green cluster contains keywords primarily associated with research and instructional settings, including "learning model," "experimental class," "control class," and "population"; it was therefore interpreted as the *instructional and research-design context* cluster. The blue cluster includes terms such as "RME," "Realistic Mathematics Education," "teacher," "effectiveness," and "data analysis" and was interpreted as the *RME implementation and evaluation* cluster. The red cluster contains terms directly associated with mathematical creativity, including "mathematical creative thinking," "fluency," "flexibility," "indicator," and "creativity"; it was therefore interpreted as the *mathematical creative thinking and indicators* cluster. These thematic labels summarize patterns of keyword co-occurrence and should not be interpreted as evidence of causal, hierarchical, or functional relationships among the concepts.

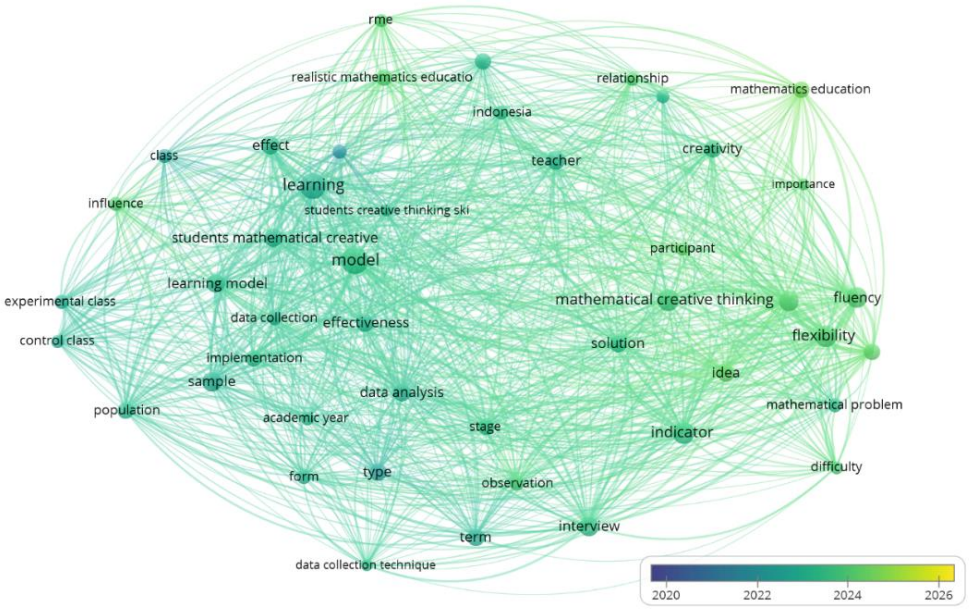


Figure 3. Temporal overlay visualization of keyword co-occurrence in the 221-record bibliometric corpus

Figure 3 presents the temporal distribution of keyword occurrences within the 221-record bibliometric corpus. The overlay visualization indicates that many frequently occurring keywords are concentrated in the 2022–2024 period, including terms related to learning and research design (e.g., “learning,” “control class,” and “experimental class”) and mathematical creative thinking (e.g., “mathematical creative thinking,” “fluency,” and “flexibility”). The visualization should be interpreted as a temporal map of frequently occurring terms rather than as direct evidence of the presence or absence of a specific research topic.

AI-related terms did not emerge prominently in the mapped keyword network under the minimum occurrence threshold of five. This pattern alone does not establish the absence of AI-related research, because emerging terms occurring fewer than five times would not appear in the visualization. However, examination of the nine primary studies included in the in-depth synthesis provides additional evidence: none empirically investigated AI-supported RME specifically in relation to MCT, whereas technology-enhanced interventions represented in the primary studies involved augmented reality and virtual reality. Therefore, the integration of AI with RME for MCT is identified here as an emerging research opportunity based primarily on the primary-study synthesis, with the bibliometric visualization providing complementary contextual evidence rather than proof of a research vacuum.

General Characteristics of the Studies

The nine studies exhibit methodological diversity, comprising one R&D study, five quantitative experimental studies (using quasi-experimental or factorial designs), one design research study, and two descriptive qualitative studies.

Regarding educational levels, the majority of the studies (six out of nine) were conducted at the junior high school level, and three at the elementary school level; notably, no primary studies explicitly targeting the senior high school level were found. The mathematical topics serving as the context for RME implementation also varied, encompassing geometry (3D and 2D shapes), general mathematics (elementary level), circles, fractions, exponents, algebra, 2D shapes, and social arithmetic. This indicates that RME has been examined across various mathematical content domains within the school curriculum.

Table 2. Characteristics of Primary Studies Included in the Synthesis

Code	Research focus	Subject Matter	Level/ Sample
A	Development of RME-based VR media for MCT skills.	Geometry (3D)	Junior High Grade IX (N=64).
B	Effect of RME on Enhancing Creative Thinking.	Elementary Mathematics	Elementary Grade IV (N=144).
C	Augmented Reality Technology (ART)-assisted RME.	Plane Figures	Elementary Grade IV (N=110).
D	RME, Prior Knowledge, and Creative Thinking.	Junior High Mathematics	Junior High Grade VIII (N=50)
E	Enhancing Creative Thinking on the Topic of Circles.	Circles	Junior High Grade VIII (N=43)
F	Ib-RME (RME with Ice-breaking Integration).	Fractions	Junior High Grade VII (N=64)
G	Analysis of Creative Thinking through RME.	Exponents	Junior High Grade VIII (N=27)
H	RME and AQ.	Algebra	Junior High Grade VII (N=35)
I	Imagination and Creative Thinking in RME.	Plane Figures & Social Arithmetic.	Elementary Grade VI (N=36)

Table 3 distinguishes learner-related constructs, instructional features, and measured outcomes rather than grouping these heterogeneous elements as affective factors. Each entry identifies its category and primary-study source (codes A–I correspond to Table 2); the findings summarize reported results without implying that every construct was directly measured or causally tested.

Table 3. Summary of Key Findings on Mathematical Creative Thinking across Included Studies

Code	Associated Factors and Features	Findings
A	VR-assisted RME (instructional feature); Ramadhani et al. (2026)	The VR-assisted RME group had a higher reported mean MCT score (83.50) than the comparison group (72.35).
B	RME instruction (instructional approach); Nisa et al. (2023)	The reported normalized gain was higher in the RME group (0.38) than in the comparison group (0.27).
C	Augmented-reality-assisted RME (instructional feature); Hurulean & Miliyawati (2024)	The study reported favorable creative-thinking outcomes associated with augmented-reality-assisted RME.
D	Initial mathematical ability (learner characteristic); Halim et al. (2020)	The instructional approach was associated with a statistically significant result ($p < .001$), while its interaction with prior mathematical ability was not statistically significant ($p = .488$).
E	RME versus expository instruction (instructional comparison); Hasibuan et al. (2024)	The RME group had a higher reported mean score (77.50) than the expository group (48.91).
F	Ice-breaking integrated with RME (instructional feature); Ramadhanta et al. (2024)	The study reported favorable MCT outcomes associated with ice-breaking-integrated RME instruction.
G	Creative-thinking proficiency (measured outcome); Erwin & Julie (2025)	Students were classified into high (11%), moderate (81.5%), and low (7.5%) creative-thinking categories.
H	Adversity quotient (learner-related construct); Tania et al. (2024)	The study described differences in creative-thinking characteristics across adversity quotient categories.
I	Imagination (investigated learner construct); Kusmaryono & Maharani (2021)	The study examined imagination and creative-thinking processes in RME-based learning.

The included quasi-experimental studies generally reported favorable mathematical creative thinking outcomes associated with RME-based instruction compared with conventional, expository, or deductive approaches. Halim et al. (2020) reported a statistically significant result for the instructional approach ($p < .001$), whereas the interaction between instructional approach and Prior Mathematical Ability (PMA) was not statistically significant ($p = .488$). However, this non-significant interaction does not establish equivalent outcomes across students with different initial ability levels. In the context of circle-related topics, Hasibuan et al. (2024) reported a higher mean score for the RME group (77.50) than for the expository group (48.91). Hurulean & Miliyawati (2024) also examined RME supported by augmented reality technology. Nevertheless, differences in study design, sample characteristics,

and statistical reporting limit causal interpretation and comparisons of effect magnitude across studies.

Findings from individual studies should be distinguished from the indicator-reporting frequencies summarized in Table 4. Nisa et al. (2023) discussed differences in creative-thinking indicators between instructional groups, whereas Erwin & Julie (2025) reported the distribution of students across creativity categories (11% high, 81.5% medium, and 7.5% low). The latter distribution describes observed categories and, without an appropriate baseline comparison, does not establish movement between levels or an intervention effect.

Ramadhanta et al. (2024) and Kusmaryono & Maharani (2021) discussed contextual learning and imagination in relation to MCT. To distinguish the indicators examined in the primary literature from their measured outcomes, Table 4 records whether each MCT indicator was assessed or reported in each included study.

Table 4. Frequency of Mathematical Creative Thinking Indicators Reported Across the Nine Included Studies

Codes	Fluency	Flexibility	Originality	Elaboration	Other
A	✓	✓	✓	✓	-
B	✓	✓	✓	✓	-
C	✓	✓	✓	✓	Sensitivity
D	✓	✓	✓	✓	-
E	✓	✓	-	✓	Sensitivity
F	✓	✓	✓	-	-
G	✓	✓	✓	-	-
H	✓	✓	✓	✓	-
I	✓	✓	✓	✓	Imagination
Total	9	9	8	7	

Note. A check mark (✓) indicates that the indicator was assessed or reported in the study; a dash (–) indicates that it was not identified in the report. Totals and percentages represent reporting frequencies across nine studies, not student-level improvement or intervention effect sizes.

Table 4 summarizes the frequency with which the four MCT indicators were assessed or reported in the nine included studies. Fluency and flexibility appeared in all nine studies (100% each), originality in eight (88.9%), and elaboration in seven (77.8%). These percentages describe the distribution of indicators in the reviewed reports; they do not indicate the proportion of students who improved, the size of any improvement, or the comparative effectiveness of RME across indicators. Differences in reporting frequency may reflect variation in assessment frameworks or study objectives, but Table 4 alone cannot establish the

reasons for these differences. Comparisons of intervention outcomes across MCT dimensions require indicator-specific results and comparable effect estimates.

Conceptually, contextual problems, guided reinvention, and progressive mathematization in RME may provide opportunities for students to generate varied strategies, refine representations, and develop original solutions. These processes are relevant to fluency, flexibility, originality, and elaboration; however, the reporting frequencies in Table 4 do not establish which dimensions respond most strongly to RME instruction. Across the included studies, quantitative findings generally favored RME-based instruction, although the designs and reported statistics varied. Accordingly, these findings are synthesized narratively rather than interpreted as a pooled causal effect or as evidence of uniform improvement across all four MCT indicators.

RME uses meaningful contexts as starting points for mathematical activity and supports students in developing and refining informal strategies (Fauzan et al., 2024; Koerunnisa et al., 2025; Wati et al., 2026). Nevertheless, the included studies do not provide sufficiently comparable indicator-specific outcome estimates to determine whether one dimension of MCT improves more than another.

The indicator mapping therefore identifies a difference in what researchers measured or reported, not a difference in student gains. In particular, the presence of fluency and flexibility in all nine reports must not be interpreted as evidence that these indicators improved in every study. Likewise, the lower frequencies for originality and elaboration do not demonstrate weaker intervention effects on these dimensions.

The included studies also examined instructional features integrated with RME, particularly augmented reality (Hurulean & Miliyawati, 2024) and virtual reality (Ramadhani et al., 2026). These studies reported favorable MCT-related findings, although the available evidence does not establish that technology integration consistently produces greater improvements across specific creativity indicators. Research on AI-supported learning provides additional conceptual context, but none of the nine primary studies directly investigated AI-supported RME in relation to MCT. Consequently, the potential contribution of AI remains a direction for future empirical investigation rather than an established finding of this review.

AI-supported learning may provide opportunities to present adaptive and contextually relevant mathematical tasks. Noverica & Simanjuntak (2026) suggest that integrating RME, Culturally Responsive Teaching, and AI may support 21st-century skills, including creativity, through more adaptive learning experiences. In the present bibliometric analysis, AI-related

terms did not emerge prominently under the minimum occurrence threshold of five. This pattern indicates that AI is not yet a prominent theme within the mapped RME-MCT literature, but it should not be interpreted as evidence that AI-related empirical research is entirely absent, as emerging terms occurring fewer than five times may not appear in the visualization. Furthermore, none of the nine primary studies included in the in-depth synthesis specifically investigated AI-supported RME in relation to MCT. Therefore, AI-supported RME is identified as an emerging direction for further empirical investigation rather than as evidence of a definitive research gap or empirical vacuum.

Beyond technological integration, classroom management strategies incorporating activities such as RME-based ice-breaking (Ib-RME) have also been examined. Ramadhanta et al. (2024) reported favorable outcomes for MCT following the implementation of Ib-RME. A conducive and enjoyable classroom atmosphere that is safe, pleasant, and non-judgmental may encourage students to explore diverse solution strategies, including those required for complex and non-routine problem-solving tasks (Han et al., 2022; Robinson & Held, 2025). Regarding students' affective characteristics, Adversity Quotient (AQ) has also been associated with students' responses to mathematical learning and problem-solving challenges (Ginting, 2024; Safi'i et al., 2021).

Regarding learner-related factors, Tania et al. (2024), examined MCT in relation to Adversity Quotient (AQ) and reported differences in creative-thinking characteristics across AQ categories, with students classified as "climbers" showing stronger performance in the reported analysis. However, this finding was derived from a single qualitative study and should not be interpreted as evidence that AQ determines the effectiveness of RME or functions as a general motivational prerequisite for MCT. Literature outside the nine-study synthesis has discussed possible relationships among AQ, motivation, and performance (e.g., Syarif, 2024); however, such evidence is used here only to provide contextual interpretation and does not constitute evidence generated by the primary studies included in this review. Therefore, the role of AQ within RME-based MCT remains an area requiring further empirical investigation.

The synthesis also identifies several directions for future research within the scope of the reviewed evidence. First, none of the nine primary studies specifically examined AI-supported RME in relation to MCT. In the broader bibliometric corpus, AI-related terms did not emerge prominently under the minimum occurrence threshold of five; however, this pattern should not be interpreted as evidence that AI-related research is entirely absent because less frequently occurring terms may not appear in the visualization. AI-supported RME may therefore be

considered an emerging direction for further empirical investigation. Second, the included studies predominantly examined immediate or relatively short-term outcomes, indicating a need for longitudinal research on the sustainability of MCT following RME-based instruction. Third, the reviewed studies reported originality and elaboration less frequently than fluency and flexibility; these differences concern reporting frequency, not intervention effects. Future studies should therefore examine all four dimensions more systematically using clearly defined and comparable measures. These research directions reflect limitations and patterns within the reviewed evidence rather than definitive gaps in the broader RME literature.

This review has several limitations that define the scope of its conclusions. First, only nine primary studies met the eligibility criteria for in-depth synthesis, resulting in a relatively small evidence base. Second, the studies were heterogeneous in research design, sample characteristics, mathematical content, instructional implementation, and MCT measurement, limiting direct comparisons and preventing conclusions about a common intervention effect. Third, the language and full-text eligibility criteria may have excluded relevant studies published in other languages or without accessible full texts. Fourth, although Scopus and ERIC were complemented by DOAJ and Crossref to broaden literature discovery, the selected information sources may not capture all relevant RME-MCT research. Finally, the included studies were concentrated at the elementary and junior high school levels, with no senior high school studies represented in the final synthesis. Consequently, the findings should be interpreted as reflecting the characteristics of the available nine-study evidence base and should not be generalized to educational levels, populations, or instructional contexts that were not represented in the review.

CONCLUSION

This systematic review synthesized nine primary studies published between 2020 and 2026 to examine RME in relation to students' MCT. Overall, the quantitative studies reported favorable MCT-related outcomes for RME-based instruction, while the qualitative and design-oriented studies provided complementary insights into students' creative-thinking processes and learning experiences. However, the methodological heterogeneity of the included studies and limitations identified through the MMAT appraisal warrant cautious interpretation of these findings.

The findings are limited by the small number of primary studies, heterogeneity in study designs and MCT measures, language and full-text eligibility restrictions, the coverage of the

selected information sources, and the absence of senior high school studies. Consequently, the conclusions should be interpreted within the educational contexts represented in the included studies rather than generalized across all student populations and educational levels. Future research should prioritize more rigorous and comparable study designs, standardized MCT measurement and effect reporting, longitudinal assessment of MCT outcomes, systematic examination of all four MCT dimensions, and empirical investigation of emerging approaches such as AI-supported RME.

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