Journal of Instructional Mathematics
E-ISSN 2722-2179
DOI: 10.37640/jim.v7i1.2761
Volume 7, Issue 1; 2026

The Role of Realistic Mathematics Education in Developing Critical Thinking Skills: A Systematic Literature Review

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Article Info

Received
January 27, 2026

Revised
March 2, 2026

Accepted
April 2, 2026

Keywords

Critical Thinking; Mathematics Learning; Realistic Mathematics Education; Systematic Literature Review.

Abstract

Although critical thinking is fundamental to 21st-century mathematics learning, research synthesizing how Realistic Mathematics Education (RME) develops this competency remains fragmented and underexplored. This study aims to map the literature profile, development trends, as well as challenges and recommendations of research related to the integration of RME and critical thinking abilities. A Systematic Literature Review (SLR) method was applied to 18 articles from Scopus and Google Scholar for the period 2019-2025 using VOSViewer bibliometric analysis. The results show that RME consistently improves critical thinking abilities through three clusters: learning implementation, RME characteristics based on real contexts, and effectiveness evaluation. Research trends evolved from effectiveness verification (2019-2021), technology integration (2022-2023), toward differentiated learning and exploration of local cultural contexts (2024-2025). This evolutionary pattern raises a critical question: whether such trends reflect the theoretical maturity of RME as a robust and coherent pedagogical framework, or whether they indicate fragmentation of approaches that risks diluting the core principles of RME. Main challenges include variations in learning design quality and limited digital infrastructure. The study recommends continuous RME implementation, strengthening of teacher education curriculum, and development of specific critical thinking measurement instruments for RME based mathematics learning are needed.

How to Cite:
Hanipa, H., Nusantara, D. S., & Rohati, R. (2026). The Role of Realistic Mathematics Education in Developing Critical Thinking Skills: A Systematic Literature Review. *Journal of Instructional Mathematics*, *7*(1), 81-96.

INTRODUCTION

The rapid development of science and technology in the 21st century demands a fundamental transformation in education to prepare a generation capable of facing global complexities (Srivastava, 2023). International organizations such as the OECD and UNESCO emphasize that higher-order thinking skills, particularly critical thinking, are core competencies that students must possess to compete and contribute in a knowledge-based economy (OECD, 2019; Wang & Abdullah, 2024). The National Education Association identifies the "4Cs" critical thinking,

creativity, communication, and collaboration as essential 21st-century skills that must be developed through the education system (Thornhill-miller et al., 2023). Mathematics, as a fundamental discipline, plays a strategic role in developing critical thinking skills, as reflected in the PISA mathematics literacy framework, which places reasoning and problem-solving at the core of assessment (D. A. Lestari & Prayitno, 2025). Despite growing interest in RME, the literature suffers from a critical gap: there is no systematic and comprehensive analysis that specifically examines how RME theoretically outperforms other instructional approaches in developing critical thinking. Existing studies tend to report isolated effectiveness data without explaining the specific mechanisms such as guided reinvention, contextual problem solving, and horizontal mathematization through which RME structurally promotes higher order thinking beyond what problem-based learning or inquiry based learning achieves.

However, reality shows a significant gap between expectations and reality. The 2022 PISA results reveal that student performance in mathematical literacy has declined globally (Huang et al., 2024), with Indonesia's mathematics score reaching 366 points, down from 379 in 2018 and far below the OECD average of 472 points (OECD, 2023). Only 18% of Indonesian students achieved the minimum proficiency level (Level 2), indicating that the majority of students have difficulty interpreting everyday situations mathematically without direct instruction (Andari & Setianingsih, 2021).

To address these challenges, RME, developed based on Freudenthal's mathematization theory, offers a strong theoretical and practical framework (Marhamah et al., 2024). RME emphasizes the use of real-world contexts as a starting point for learning, encouraging students to construct mathematical concepts through meaningful activities and a gradual mathematization process (Da, 2022). A number of recent studies have shown the effectiveness of RME in improving critical thinking skills at various levels of education (Hikayat et al., 2020; Pramartha et al., 2025). However, there is no systematic literature review that comprehensively maps the research profile, development trends, challenges, and recommendations related to the integration of RME with the development of critical thinking skills. Existing reviews are either partial in scope (focusing on a single education level or country), limited meta-analysis that do not address critical thinking as a primary outcome, or SLR on RME that omit critical thinking as the central analytical lens. This study fills that gap by providing the first comprehensive SLR that explicitly integrates both RME and critical thinking development across contexts, levels, dan time periods. Therefore, this study was conducted to answer four research questions: (RM1) What is the research literature profile on the role of RME in developing critical thinking skills?; (RM2) What are the trends in RME research related to the improvement of critical thinking over the past decade?; (RM3) What are the challenges and recommendations of previous research on the integration of RME and critical thinking?; (RM4) What are the theoretical implications of the findings for the development of the RME framework and the measurement of critical thinking in mathematics education?

RM1 aims to explore the research literature on how the RME approach plays a role in developing critical thinking skills. This analysis will describe the key characteristics of scientific publications, including year of publication, publisher

journal, methodological approach, research findings, and recommended suggestions. RM2 is intended to map research trends on the implementation of RME in improving critical thinking skills in mathematics learning over the past decade. RM3 focuses on identifying obstacles and limitations found in previous studies on the integration of RME with critical thinking development, in order to broaden insights into the implementation of RME in the future. This systematic literature review presents a comprehensive review of the available literature on the contribution of the RME approach to improving critical thinking skills, including an in-depth understanding of the various findings produced by previous researchers.

RESEARCH METHODS

This study applied the systematic literature review (SLR) method to identify and examine relevant research thoroughly through the collection, analysis, and critical evaluation of data from studies that met the criteria of. SLR was chosen because it was appropriate for the purpose of exploring the role of RME in improving critical thinking skills based on previous research, while also identifying gaps and limitations in these studies. The SLR process was carried out through three core stages: planning, implementation, and reporting (Amrullah & Pane, 2023), as shown in Figure 1.

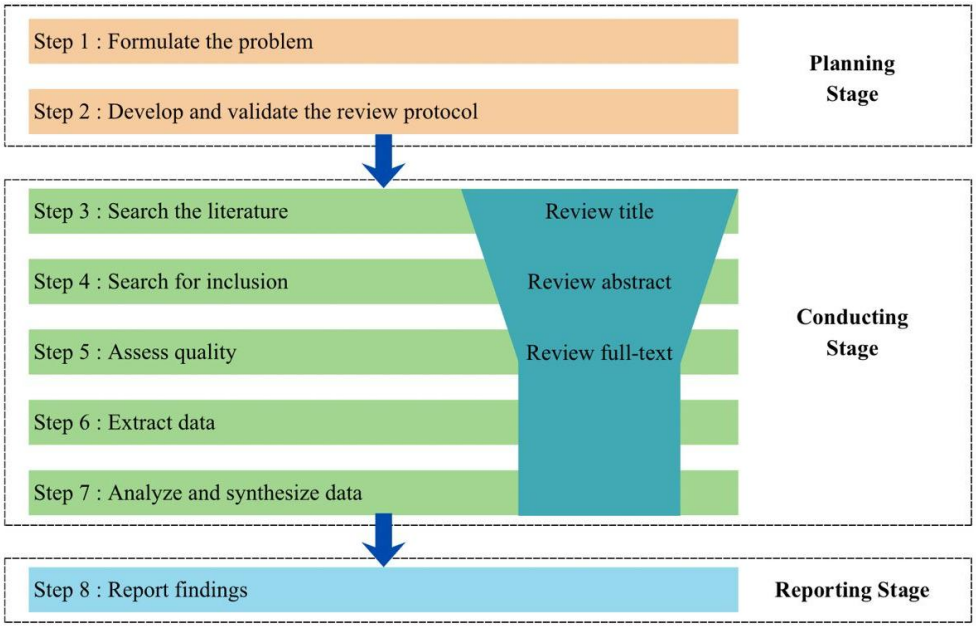

Figure 1. Steps in Systematic Literature Review

Review Planning

During the planning stage, researchers determine the required components, select relevant studies, and develop a review protocol (Pollock & Berge, 2018). In developing the protocol, researchers make three key decisions: first, they formulate keywords to search for relevant literature; second, they use the Scopus and Google Scholar (specifically, 11 articles from Scopus and 7 from Google Scholar) databases to find studies that meet the criteria; third, they set inclusion

and exclusion criteria to ensure that the selected literature is relevant to the focus of the review.

Conducting the Review

This review began with several stages, namely literature search, selection based on inclusion criteria, data collection, analysis and synthesis of information, and ended with the preparation of a report. The literature was obtained from three main sources: electronic databases, backward searches, and forward searches. In this study, Scopus was chosen as the main database to identify relevant literature, while Google Scholar was used as an additional source to find other articles. The inclusion and exclusion criteria set out in Table 1 were useful for ensuring the relevance and quality of the literature reviewed.

Table 1. Search Keywords, Databases, Inclusion and Exclusion Criteria

Database	Scopus (primary database) Google Scholar (Secondary database)
Title Keywords	"Realistic Mathematics Education" and "Critical Thinking"
Keywords	"Critical Thinking" and "Realistic Mathematics Education" "Critical Thinking" and "PMRI" "Mathematical Critical Thinking" and "Realistic Mathematics Education" "Critical Thinking" and "RME"
Screening Criteria	– One of the selected keywords does not appear in the title, abstract, keywords, or full text – Not in English – Outside the scope of mathematics education
Inclusion Criteria	– One of the selected keywords appears in the title, abstract, keywords, or full text – Is it an article or thesis? – Published in English or Indonesia by Indonesian authors or addressing Indonesian educational contexts

Initial screening was conducted using title keywords, article keywords, and relevant databases, resulting in the identification of 139 articles from Scopus (n=89) and Google Scholar (n=134) as shown in Table 2. Next, the articles obtained were evaluated and duplicate articles and those that could not be accessed were eliminated, leaving 94 articles. Then, the titles and abstracts were analyzed using inclusion and exclusion criteria.

We found 40 articles that met the criteria, while 54 others did not meet the requirements. Of the 40 articles that passed the selection, 18 articles were considered to have the potential to answer the research questions. The document screening process can be seen visually at Figure 2.

The PRISMA selection process is described at Figure 2, from the data search stage to the final sample. After determining 18 articles that were considered relevant for further review and analysis, each article was coded based on various aspects, such as author name, year of publication, journal source, title, article type, research method, objectives, problem formulation, main findings, limitations, and

recommendations for further research. In addition, quantitative network analysis was performed using VOSViewer bibliometric software.

Table 2. Search Results Based on Database, Title Keywords, and Keywords

Words in Title	Keywords	Scopus	Google Scholar
Critical Thinking dan Realistic Mathematics Education	"Critical Thinking" and "Realistic Mathematics Education"	40	-
	"Critical Thinking" and "PMRI"	9	-
	"Mathematical Critical Thinking" and "Realistic Mathematics Education"	19	-
	"Critical Thinking" and "RME"	21	50
	Number of documents	89	50
Total number of all documents		139	

Review Reporting

Compiling a valid and replicable literature review requires the presentation of complete documentation of the systematic study process, including an explanation of the reasons for establishing each inclusion and exclusion criterion. In addition, the results of the literature search, screening, and quality evaluation processes must also be presented. In this study, the review findings were analyzed using the VOSViewer application to map the network of interrelationships.

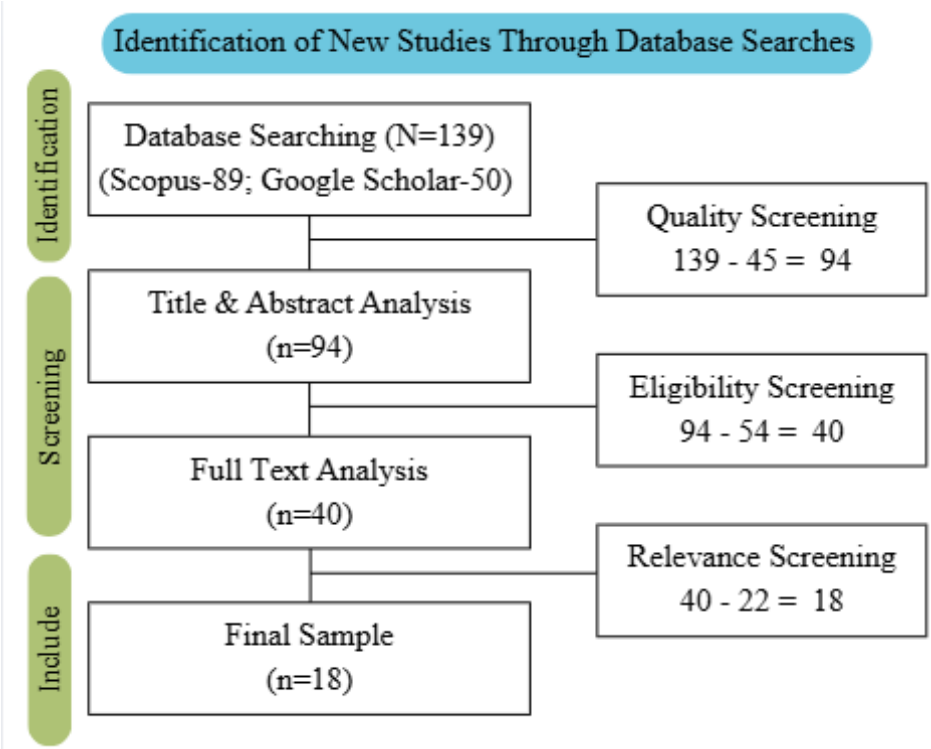

Figure 2. PRISMA Based Selection Process

RESULTS AND DISCUSSION

This study conducted three types of analysis, namely research and network profile analysis, qualitative analysis, and analysis of challenges and recommendations from previous studies. The results of this literature review indicate a trend of increasing publications in recent years, as shown in Figure 3 regarding the number of studies per year on the RME approach to critical thinking skills. It is important to note, however that not all included studies carry equal methodological weight. The reviewed studies span a range of research design including quasi-experimental studies, design research, and development studies each with distinct levels of internal validity and generalizability. Quasi-experimental studies provide stronger casual evidence regarding the effectiveness of RME on critical thinking, while design research and development studies offer insights into the design process and usability but with more limiter evidence of causal effect. The following discussion differentiates findings based on the strength of evidence produced by each study type, in order to avoid conflating exploratory findings with confirmatory ones.

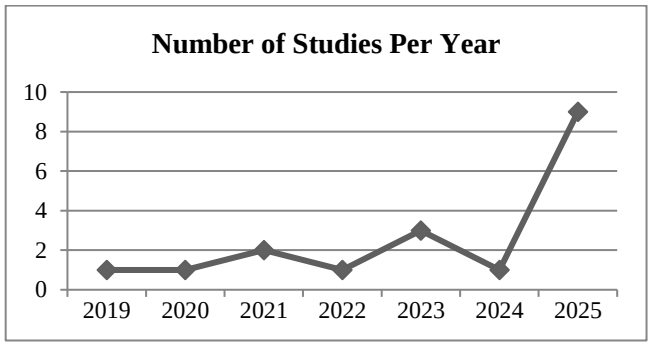

Figure 3. Number of Studies Per Year
on the RME Approach to Critical Thinking Skills

This study analyzes keyword networks using bibliometric visualization. The network analysis generated through VOSviewer shows the interrelationships between keywords in studies on the role of RME in the development of critical thinking skills.

Network analysis at Figure 4 shows three main clusters of 50 keywords with 324 connections. The central nodes are "realistic mathematics education," "critical thinking," and "skill," indicating that RME research is consistently associated with the development of critical thinking skills. The first cluster focuses on critical thinking skills and learning implementation. The second cluster emphasizes the characteristics of RME and the learning process in a real-world context. The third cluster assesses the effectiveness of RME through quantitative indicators and experimental design. The three clusters complement each other: the second cluster describes the basic concepts of RME, the first cluster shows its application, and the third cluster provides empirical evidence of its effectiveness.

Theoretically, the first cluster aligns with Bloom's higher-order thinking taxonomy, particularly the analysis, evaluation, and creation levels that RME's guided reinvention principle is designed to activate. The second cluster directly reflects the five tenets of Freudenthal's RME theory phenomenological

exploration, guided reinvention, emergent modeling, didactical phenomena, and intertwinement confirming that contextual learning is the theoretical backbone of RME's effectiveness. The third cluster connects to evidence-based education discourse, demonstrating that the empirical claims of RME have been tested through experimental and quasi-experimental designs, though with varying methodological rigor.

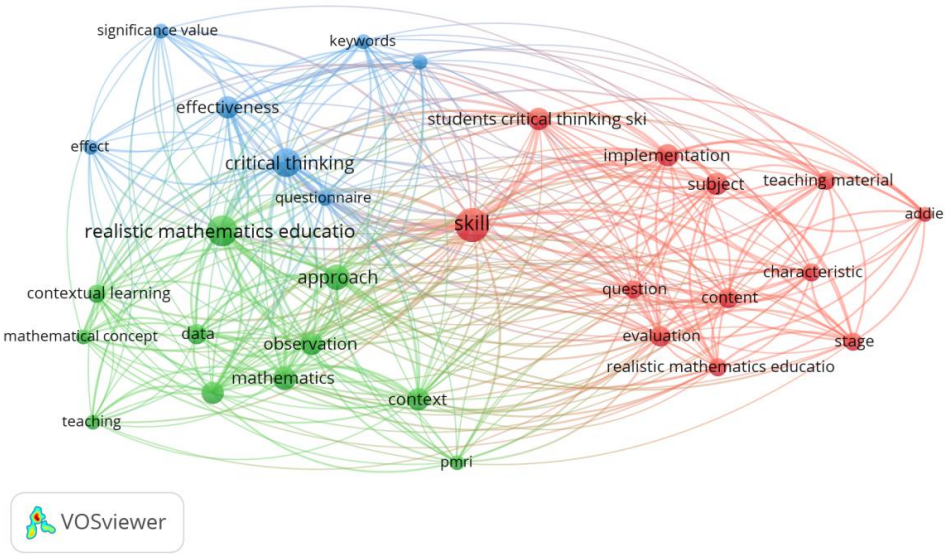

Figure 4. Keyword Network of Literature Research on the RME Approach to Critical Thinking Skills

The overlay visualization in Figure 5 shows the temporal development of RME research. The blue-green color indicates early research (2022-2023), while yellow indicates recent research (2024-2025). "Realistic mathematics education" in green indicates RME as a consistently developing foundation, while "critical thinking" tends to be yellow, indicating that the relationship between RME and critical thinking is strengthening in recent research.

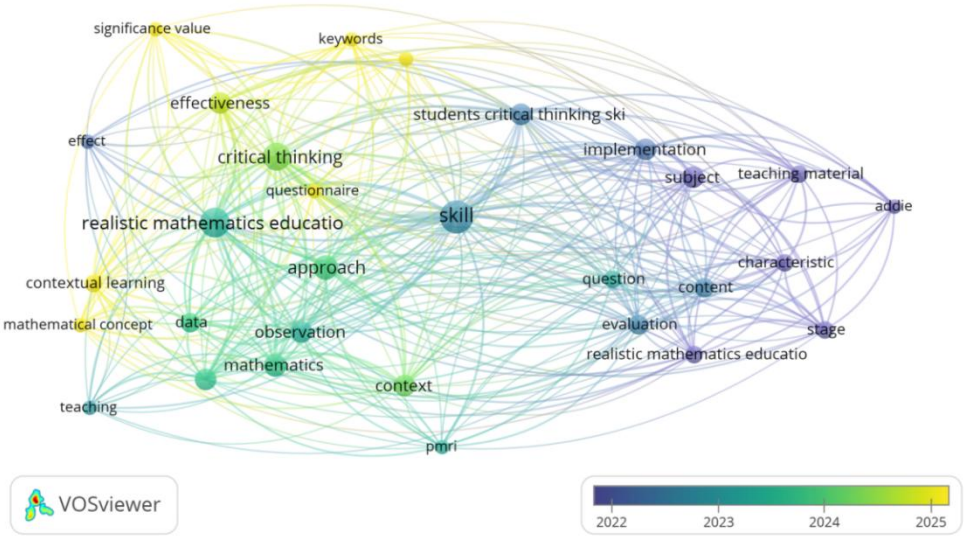

Figure 5. Overlay Visualization for the RME Approach to Critical Thinking Skills

The visualization shows that evaluation keywords such as "effectiveness," "significant value," and "significant difference" appear frequently in 2024-2025 (yellow), indicating that recent studies emphasize empirical evidence of RME's effectiveness. Meanwhile, basic RME keywords such as "contextual learning," "approach," and "teacher" are colored green-blue, signifying that the theoretical and pedagogical foundations of RME have been studied for longer before developing into research on its impact on critical thinking. The density visualization in Figure 6 at highlights the intensity of keyword occurrences to identify dominant research topics.

Density visualization in Figure 6 shows the highest research intensity (bright yellow) on the keywords "skill," "critical thinking," and "realistic mathematics education," confirming all three as the main focus of the literature. The areas surrounding "effectiveness," "approach," "mathematics," "contextual learning," and "implementation" show moderate density as supporting components. Meanwhile, "pmri," "addie," and "teaching material" are in the bluish-green area with lower intensity.

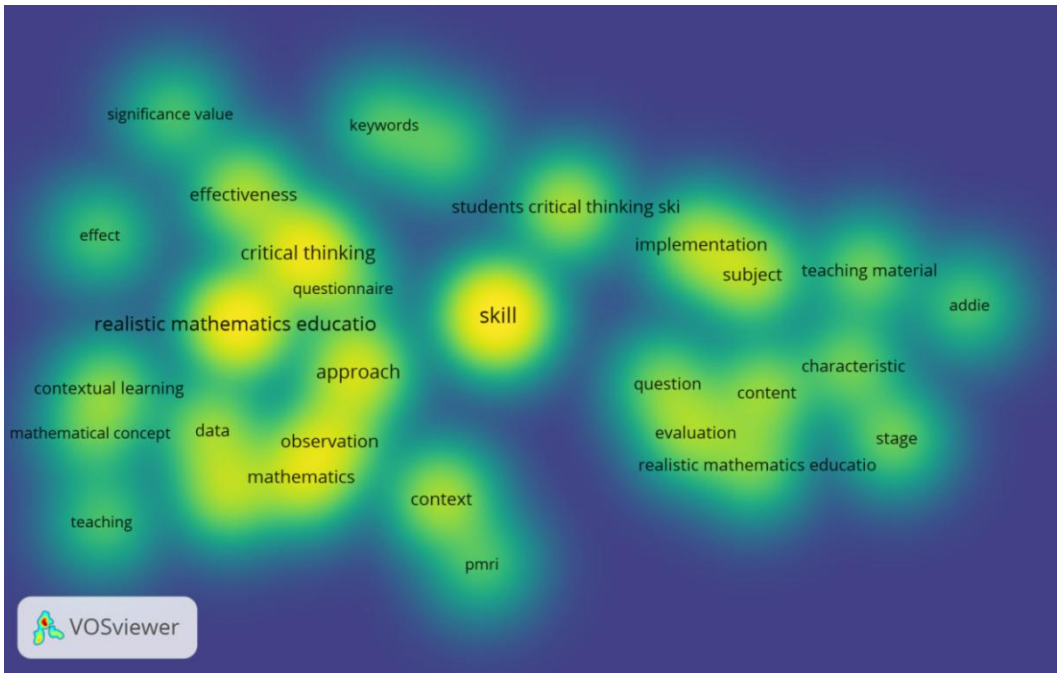

Figure 6. Density Visualization of RME Approach to Critical Thinking Skills

Overall, the literature is highly focused on the relationship between RME, critical thinking skills, and student skill development, while implementational and methodological variables receive more limited attention. This reinforces that the development of critical thinking skills through RME is central to the research discourse analyzed.

Furthermore, content analysis or a qualitative approach was applied to the reviewed literature to answer RM2. Specifically, trends in RME and critical thinking research development were analyzed based on the literature presented in Table 3.

Table 3. Focus of RME and Critical Thinking Research Used

Author	Results	Recommendations
Yulia et al. (2019)	RME HLT helps students develop their own strategies, understand set concepts, and demonstrate improved critical thinking skills.	Teachers are advised to use RME-based HLT, start from concrete contexts and move towards abstraction; design student responses in lesson plans.
Hikayat et al. (2020)	The module received excellent scores from validators and is suitable for use.	RME-based modules can be applied to enhance critical thinking.
Afriansyah et al. (2021)	RME-EM further improves MCTS; there is no significant interaction between MPK & learning model.	RME-EM can be used as an alternative to improve MCTS.
Cahyaningsih et al. (2021)	RME improves critical thinking skills more than conventional learning.	RME is recommended to be implemented in elementary schools.
Paratiwi et al. (2022)	The average critical thinking ability of students was in the "good" category with indicators of interpretation 0.79, reflection 0.79, evaluation 0.76, analysis 0.78, and inference 0.79.	Using simple contextual problems so that students can focus on the critical thinking process and improve their analytical skills.
Edwar et al. (2023)	Teacher competence increased from 45.70% to 85.70%. HOTS questions are more contextual (e.g., the context of duku fruit) and improve students' critical thinking skills.	Andragogy-based workshops need to be widely implemented; use PMRI to create HOTS questions; continuous coaching is recommended.
Hough et al. (2023)	Teachers demonstrated increased understanding of student thinking and more equitable teaching practices.	Further research is needed on the development of equitable learning amid accountability pressures.
Lestari et al. (2023)	Worksheets are valid (expert), practical (student response), and effective (pretest–posttest improvement).	RME-based worksheets are recommended to improve students' critical thinking skills.
Utami et al. (2024)	Cultural context enhances critical thinking skills and understanding of geometric concepts	Expand the use of local culture as a context for mathematics learning

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Table 3. (*continued*)

Pramartha et al. (2025)	1) There was a significant increase in conceptual understanding and critical thinking (*p*-value=0.000). 2) The e-module products met the criteria of validity, practicality, and effectiveness according to validators, lecturer & student responses, and field observations. 3) E-module features: instructions independent learning on contextual problems, GeoGebra integration, interactivity, self-evaluation (Google Forms), and independence from other materials.	1) The RME e-module is recommended for implementation in higher education for the topic of functions (to strengthen conceptual understanding and critical thinking). 2) Develop other topics disseminate this model; conduct further research on a larger scale and for a variety of study programs. 3) Conduct socialization and training for lecturers prior to implementation (to improve practicability).
Nurhaswinda et al. (2025)	Scores increased from 62.5 (pre-cycle) to 82.3 (cycle II). Student activities were more active and logical.	RME needs to be applied continuously; teachers need to be trained to design real-world contexts for learning.
Ramadan et al. (2025)	The average score increased by 40 points; *p*-value<0.001. Students were more active and understood the concepts better.	Improvements in digital infrastructure and teacher training are needed; the use of technology is recommended for geometry material.
Pramartha et al. (2025)	*p*-value=0.000; there was a significant improvement in concepts and critical thinking. The module is interactive, contextual, and self-directed.	RME e-modules are recommended for higher education; they can be applied in various mathematics courses.
Alim et al. (2025)	*n*-gain 61.08 (moderately effective); *p*-value=0.00; RME-based differentiation has a significant effect.	RME + differentiation is recommended for heterogeneous classes; teachers need to map students' initial abilities.
Irmayani et al. (2025)	There was a significant increase in critical thinking skills.	RME is recommended as a meaningful and contextual approach.
Putri et al. (2025)	practices show changes in teaching identity, increased use of representations, and improved learning quality.	It is recommended to use co-teaching as a PPL strategy; prospective teachers must evaluate the reasons for choosing representations; assistant teachers need to be trained in RME design.

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Table 3. (*continued*)

Mulbasari et al. (2025)	The PMRI learning environment is valid and practical; it effectively improves critical thinking (Ennis) and pedagogical (Guskey) skills.	Integrate PMRI into teacher education; use contextual activities; the need for continuous practice-based and reflective training.
Sari et al. (2025)	Design quality varies; some are strong (equivalent ratios, quadratic equations) but other topics are still superficial	Deeper integration of RME principles in teacher education and curriculum is needed

Temporal analysis based on shows the evolution of RME research focus and critical thinking: in the 2019-2021 period, research focused on developing basic learning designs (HLT, modules) and proving the effectiveness of RME through quasi-experimental studies at the elementary and secondary school levels. Proof of effectiveness (Afriansyah et al., 2021; Cahyaningsih & Nahdi, 2021), module development (Hikayat et al., 2020), and HLT design (Yulia et al., 2019). This period laid the theoretical and empirical foundations for RME and critical thinking research. The main focus was on developing systematic learning designs (HLT, modules) and proving their effectiveness through comparative studies. This period answered the fundamental question: "Is RME effective in improving critical thinking?" with a consistent answer: Yes, RME has been proven effective.

Period 2022-2023, emergence of technology integration (animated videos, e-learning) and development of teacher competencies through professional workshops. Teacher professional development (workshops) (Edwar et al., 2023; Pratiwi et al., 2022), educational justice perspective (Hough & Solomon, 2023), LKS media development (R. Lestari et al., 2023). This period marked a phase of transition and diversification. Research no longer focuses solely on "whether RME is effective" but shifts to the question "how can RME be adapted and optimized?" through integration of digital technology (animated videos), strengthening teacher capacity (workshops, narrative inquiry), development of validated learning media (LKS), and broadening perspectives toward educational equity.

Period 2024-2025, Trends are moving toward integrating RME with innovative approaches differentiated learning (Alim et al., 2025), VSR (Irmayani & Irvan, 2025), digital technologies such as Assembler Edu (Ramadan et al., 2025) and interactive e-modules (Pramartha et al., 2025), exploration of local cultural contexts (Utami & Pramudiani, 2024), and professional development of prospective teachers through co-teaching (Putri et al., 2025). This period marks a critical point where RME research no longer questions its effectiveness but focuses on how RME can be integrated into complex educational ecosystems (Nurhaswinda et al., 2025), adapted to various contexts (culture, technology, level), transformed into teacher pedagogical competencies (Mulbasari et al., 2025), and linked to global issues (SDGs, educational justice).

The findings of this SLR carry significant theoretical implications for the further development of the RME framework. The three cluster structure identified through bibliometric analysis covering learning implementation, RME

characteristics in real contexts, and effectiveness evaluation reflects the theoretical architecture of Freudenthal's mathematization principle. Specifically, the consistency of the second cluster (contextual learning and RME characteristics) across all three temporal periods (2019-2021, 2022-2023, and 2024-2025) suggests that the phenomenological and contextual foundations of RME remain theoretically stable even as its practical applications diversity. This stability indicates theoretical maturity: RME's core principles have not been diluted by its expanding scope but rather serve as the unifying foundation upon which new adaptations such as integration with differentiated learning, ethno-RME, and digital e-modules are built.

A second critical theoretical implication concerns the measurement of critical thinking in the context of RME. Across the 18 reviewed studies, critical thinking was assessed using a variety of instruments including Ennis's Critical Thinking Dispositions, custom indicator based tests, and HOTS based rubrics but none of these instruments was specifically designed to capture the situated, context dependent nature of critical thinking that RME promotes.

Challenges and Recommendations for Implementation

Various challenges and recommendations emerge from the synthesis of literature related to the application of RME in improving critical thinking skills. The main challenges include variations in the quality of RME-based learning designs, especially among prospective teachers who have not fully mastered the principles of developing realistic context-based teaching materials (Sari et al., 2025). In addition, limitations in digital infrastructure and teacher competence in integrating technology are obstacles to the use of modern learning media that should support the implementation of RME (Ramadan et al., 2025). Another challenge is the need to map students' initial abilities so that teachers can apply differentiated learning appropriately, given that RME requires different conceptual readiness in each group of students (Alim et al., 2025).

In response to these challenges, the literature provides a number of recommendations. The implementation of RME is recommended to be carried out continuously, with a focus on providing training for teachers in designing real contexts that are in line with students' learning experiences (Mulbasari et al., 2025; Nurhaswinda et al., 2025). In addition, the integration of RME principles needs to be strengthened in the teacher education curriculum so that the pedagogical competence of prospective educators can be built from the outset (Mulbasari et al., 2025; Putri et al., 2025; Sari et al., 2025). The use of local culture as a learning context is also recommended to enhance the meaningfulness of reality-based mathematics learning (Utami & Pramudiani, 2024). Before RME-based learning products are implemented, socialization and training are needed so that teachers understand how to utilize these products optimally (Pramartha et al., 2025). Furthermore, the development of digital infrastructure and technology training is an urgent need to support the use of more innovative RME-based learning media (Ramadan et al., 2025).

Overall, this SLR confirms that RME is an effective approach in improving critical thinking skills at various levels of education. The successful implementation of RME is reinforced by the development of innovative learning media, integration with other learning approaches, the use of meaningful realistic

contexts, and the continuous professional development of teachers. Research trends over the past decade show a shift from merely proving effectiveness to integrating technology, differentiating learning, and strengthening teachers' pedagogical competencies in implementing RME holistically. Theoretically, these findings imply that RME's effectiveness in developing critical thinking is not incidental but is structurally embedded in its core principle of mathematization the process by which students move from informal, context based reasoning toward format mathematical thinking. This process inherently demands higher order cognitive operations such as analysis, synthesis, and evaluation, which are central components of critical thinking. Methodologically, the findings highlight a persistent gap: the majority of studies rely on per-test/post-test designs without control group comparisons, limiting causal claims about RME's effectiveness. Future research should prioritize randomized controlled designs or systematic comparisons with other active learning approaches to generate stronger, more generalizable evidence.

CONCLUSION

A systematic literature review of 18 relevant articles produced three main findings that answer the research questions. First, the literature profile shows that RME is consistently associated with the development of critical thinking skills through three main clusters: learning implementation, characteristics of RME based on real contexts, and evaluation of effectiveness. Bibliometric analysis identified "realistic mathematics education," "critical thinking," and "skill" as dominant keywords with 324 inter-concept relationships, confirming the effectiveness of RME at various education levels.

Second, the 2019-2025 research trend shows an evolution in three phases: the 2019-2021 period focuses on developing learning designs and proving effectiveness; the 2022-2023 period marks a transition with the integration of digital technology and strengthening teacher competencies; while the 2024-2025 period leads to the integration of RME with differentiated learning, exploration of local cultural contexts, and professional development of prospective teachers.

Third, the main challenges include variations in the quality of learning design, limitations in digital infrastructure, and the need to map students' initial abilities. The literature recommends the sustainable implementation of RME, strengthening the teacher education curriculum, utilizing local culture, conducting socialization prior to implementation, and developing digital infrastructure and technology training. Further research is recommended to conduct longitudinal studies to measure the long-term impact of RME, explore integration with adaptive learning technologies such as artificial intelligence, conduct cross-cultural comparative research for effective local contexts, qualitative studies on the transformation of teachers' pedagogical identities, and the development of critical thinking measurement instruments specific to RME-based mathematics learning to standardize the evaluation of the effectiveness of this approach.

Among these research directions, three are identified as most empirically and theoretically urgent: (1) the development or RME specific critical thinking measurement instruments, as the current reliance on generic instruments fails to capture the contextualized nature of critical thinking promoted by RME; (2)

longitudinal studies on the sustained impact of RME beyond the classroom, as no existing study has tracked long-term critical thinking development across school constructivist approaches, which would clarify whether the gains attributed to RME are unique to its design principles or common to all student centered pedagogies.

ACKNOWLEDGMENT

The author would like to express their appreciation to the researchers whose articles were used as sources in this review for their contributions to the development of science. Thanks are also extended to the reviewers for their constructive input and suggestions for improving this article.

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