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Systematic Literature Review (SLR): The Effectiveness of the ICARE Learning Model on Students' Mathematical Critical Thinking Skills

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ABSTRACT

The low level of students' mathematical critical thinking skills remains a significant challenge in 21st-century mathematics education. This condition highlights the need for instructional models that actively engage students in processes of analysis, evaluation, and reflection. One instructional model considered to have the potential to foster these skills is the ICARE model (Introduction, Connection, Application, Reflection, and Extension). This study aimed to review and synthesize research findings regarding the effectiveness of the ICARE learning model in improving students' mathematical critical thinking skills. The study employed a Systematic Literature Review (SLR) approach based on the PRISMA guidelines. Articles were identified through the Google Scholar database using the Publish or Perish application with the keywords ("ICARE") AND ("Critical Thinking") AND ("matematika"). The final search was conducted in May 2026 and covered publications from 2016 to 2026. The articles were screened according to inclusion and exclusion criteria, including document type, topic relevance, full-text availability, research participants, and the alignment of research variables. Of the 376 articles initially identified, 10 studies met the eligibility criteria and were included in the review. Data were analyzed through coding, categorization, comparison, and synthesis of the research findings. The results indicate that most studies reported positive effects of the ICARE learning model on students' mathematical critical thinking skills. Improvements were consistently observed in students' abilities to analyze, interpret, evaluate, infer, and draw conclusions. Furthermore, the effectiveness of ICARE was supported by learning activities that promote active participation, reflection, and contextual understanding. These findings suggest that the ICARE model has considerable potential as an alternative instructional approach in mathematics education to enhance students' mathematical critical thinking skills.

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Introduction

The development of education in the 21st century is becoming increasingly dynamic in line with rapid advances in science and technology, which continue to reshape the competencies required of students. One of the essential competencies in 21st-century learning is critical thinking, which is included as part of the 4C skills framework (critical thinking, communication, creativity, and collaboration). Critical thinking has been widely recognized as a key competency in contemporary education and has received substantial attention at both national and international levels (Samudra et al., 2025). This competency is essential because students are expected not only to comprehend information but also to analyze, evaluate, and make logical decisions in solving various learning problems. International assessments such as the Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development, indicate that Indonesian students' performance in reasoning, analysis, and problem-solving remains below the OECD average (OECD, 2019, 2023). Although PISA does not directly measure mathematical critical thinking skills, these results reflect that students' higher-order thinking abilities still require significant improvement in mathematics education. This highlights the importance of systematic efforts to enhance students' critical thinking skills, particularly in mathematics, which inherently requires analytical, evaluative, and logical reasoning abilities (Subro & Fawaid, 2025).

Mathematical critical thinking is defined as the ability to interpret, analyze, evaluate, and draw logical conclusions in solving mathematical problems. This skill enables students to understand information in depth, assess solution strategies, and make decisions based on rational justification. Therefore, critical thinking skills should be developed through learning environments that promote Higher Order Thinking Skills (HOTS) (Pelle et al., 2024). In this regard, mathematics education plays a crucial role in fostering such skills (Aryani et al., 2024). Higher Order Thinking Skills (HOTS) occur when students are able to connect prior knowledge with new information and process it to solve problems or achieve specific learning objectives (Haryadi & Pujiastuti, 2022). In mathematics learning, critical thinking is particularly important because it requires not only procedural fluency but also reasoning, analysis, and evaluation in a systematic problem-solving process (Zainal et al., 2025). Mathematics instruction itself involves various methods and strategies designed to help students understand, apply, and develop mathematical knowledge (Oktaviani et al., 2025).

However, various studies have shown that students' mathematical critical thinking skills remain relatively low. Students often experience difficulties in understanding problems, identifying relevant information, and determining appropriate solution strategies. This condition is influenced by their tendency to prioritize memorization of formulas rather than developing a deep conceptual understanding, which leads to difficulties when facing non-routine problems requiring reasoning and analysis (Intani et al., 2024). As a result, students struggle to construct systematic solution steps and to draw appropriate conclusions from given problems (Nurmalita & Zulkarnaen, 2023).

The challenges in mathematics learning are influenced by multiple factors originating from both students and teachers, thus requiring appropriate instructional strategies to address them (Maryanto et al., 2023). The development of students' critical thinking skills is strongly affected by the instructional model used by teachers. Teacher-centered learning tends to position students as passive recipients of information, thereby limiting opportunities to develop critical thinking skills. Consequently, students are more exposed to receiving information rather than actively processing and analyzing it. Therefore, learning models that actively engage students are needed to foster analytical and reflective thinking. Instructional designs that emphasize active student participation have been shown to enhance conceptual understanding and critical thinking development (Pujiastuti et al., 2021). Student-centered and problem-

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solving-oriented learning models have also been proven effective in improving mathematical critical thinking skills, as they encourage students to engage in systematic processes of analysis, evaluation, and problem resolution (Sihotang et al., 2023).

One instructional model that can be implemented is the ICARE model (Introduction, Connection, Application, Reflection, and Extension), which is designed to promote active student engagement in learning. This model emphasizes a structured learning sequence, starting from concept introduction to knowledge extension. The introduction stage ensures students' initial readiness and understanding; the connection stage links new material with prior experiences and learning objectives; the application stage provides opportunities to apply concepts in problem-solving contexts; the reflection stage facilitates evaluation and re-explanation of understanding; and the extension stage strengthens and expands learning through follow-up tasks (Hikmatuprilla et al., 2021).

Theoretically, the ICARE stages are closely aligned with indicators of mathematical critical thinking skills. The introduction stage supports students in understanding problems and identifying initial information. The connection stage helps students relate new concepts to prior knowledge, thereby enhancing interpretation and analysis skills. The application stage provides opportunities to apply concepts in problem-solving situations that involve evaluation and inference. The reflection stage supports metacognitive processes by encouraging students to review their thinking and solutions, while the extension stage broadens conceptual application to more diverse contexts. Thus, the ICARE framework has strong conceptual potential to support the development of students' mathematical critical thinking skills.

Several studies have reported that the implementation of the ICARE model has positive effects on students' critical thinking skills through concept application, discussion, and reflection activities (Rahmi et al., 2023; Yenni et al., 2022; Yulianto et al., 2024). However, these findings are still dispersed across different educational contexts, grade levels, and research designs, resulting in an incomplete understanding of the overall effectiveness of the ICARE model in improving mathematical critical thinking skills. Previous studies have also been predominantly individual empirical reports that emphasize general support for ICARE, but have not presented a critical synthesis of the patterns of findings, implementation variations, and the relationship between ICARE syntax and mathematical critical thinking skills.

Furthermore, there has been no Systematic Literature Review (SLR) that specifically integrates various studies on the effectiveness of the ICARE learning model on students' mathematical critical thinking skills. The SLR approach is necessary to provide a systematic, transparent, and structured synthesis of relevant research findings. Through SLR, research findings, implementation patterns, and limitations of previous studies can be identified, providing a stronger foundation for further research (Liani, 2025). Accordingly, this study contributes to the literature by synthesizing existing findings on the effectiveness of the ICARE model and mapping the relationship between its instructional stages and students' mathematical critical thinking skills.

Based on the discussion above, this study aims to examine and synthesize research findings regarding the application of the ICARE learning model in relation to students' mathematical critical thinking skills. Specifically, this study addresses the following research questions: (1) What are the trends in research findings regarding the implementation of the ICARE model in improving students' mathematical critical thinking skills? (2) How are the ICARE stages related to indicators of mathematical critical thinking skills? (3) What factors support the implementation of the ICARE model in mathematics education?

Method

Research Design

This study employed a Systematic Literature Review (SLR) approach. An SLR is a secondary research method conducted in a systematic, transparent, and structured manner to identify, evaluate, and synthesize research findings relevant to a particular topic. The method was used to obtain a comprehensive understanding of the effectiveness of the ICARE learning model in enhancing students' mathematical critical thinking skills based on existing empirical studies. This is consistent with the view that an SLR is intended to "identify, analyze, and synthesize findings from relevant studies" (Astagisa & Malik, 2025). Furthermore, an SLR involves "collecting and documenting all articles with similar research topics" to produce a structured and systematic body of evidence (Khairani & Nisa, 2024). The search and selection of articles followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide evidence-based reporting standards to ensure that the review process is conducted in a transparent, rigorous, and structured manner (Sastypratiwi & Nyoto, 2020). The PRISMA framework consists of four stages: identification, screening, eligibility, and included. These stages were applied to ensure that the selected studies were aligned with the objectives of this review. A PRISMA flow diagram was used to illustrate the article selection process from the initial search to the final set of studies included in the review.

Instruments

The instruments used in this study consisted of a documentation form, an inclusion–exclusion criteria table, and an article quality appraisal form. The documentation form was used to record essential information from each study, including the author(s), year of publication, educational level, research design, research instruments, findings, and conclusions. Documentation, coding, sorting, and categorization of the studies were carried out manually using Microsoft Excel to facilitate a systematic and organized review process. The quality appraisal form was used to assess the methodological quality of the selected studies. The assessment was conducted using five quality indicators (Q1–Q5) based on predetermined criteria as shown in Table 1.

Table 1. Quality Appraisal Criteria

Code	Assessment Criteria
Q1	The research objectives are clearly stated
Q2	The research methods are described in detail
Q3	The research instruments are clearly explained
Q4	The research results are presented comprehensively
Q5	The conclusions are consistent with the research findings

Studies receiving scores between 4 and 5 were categorized as high-quality studies and were included in the final synthesis, whereas studies scoring below 4 were excluded from further analysis. The inclusion and exclusion criteria applied in this review are presented in Table 2.

Table 2. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication year	2016–2026	Outside 2016–2026
Document type	Scientific journal articles	Theses, dissertations, proceedings, books
Language	Indonesian	Other languages
Research topic	ICARE learning model	Not discussing ICARE

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Criteria	Inclusion	Exclusion
Research variable	Mathematical critical thinking skills	Not relevant to mathematical critical thinking
Article access	Full text available	Full text not available
Article completeness	Has abstract	No abstract
Research subject	Students	Teachers or university students

Data Collection Procedure

Data were collected through the Google Scholar database using the Publish or Perish (PoP) application. The final search was conducted in May 2026 using the Boolean search string: ("ICARE") AND ("berpikir kritis") AND (“matematika”). To ensure the relevance and recency of the literature, the search was limited to studies published between 2016 and 2026. The initial search identified 376 articles. After removing duplicate records, 373 articles remained. Subsequently, studies were screened based on publication year (2016–2026) and document type (peer-reviewed journal articles), resulting in 184 articles.

The screening stage involved reviewing article titles and abstracts using Microsoft Excel to categorize studies according to their relevance to the research topic. Articles were excluded if they did not discuss the ICARE learning model, did not focus on mathematical critical thinking skills, were unrelated to mathematics education, or involved inappropriate research subjects. Following this stage, 45 potentially relevant articles remained. The eligibility stage involved a comprehensive full-text review of the remaining articles. Studies were excluded if they did not specifically examine the effectiveness of the ICARE model, lacked a clearly described research methodology, provided insufficient research data, or failed to meet the quality appraisal criteria. After applying the inclusion and exclusion criteria and conducting the quality assessment, 10 articles were deemed eligible for inclusion in the final review. The overall article selection process is presented in a PRISMA flow diagram, illustrating the identification, screening, eligibility, and included stages in a systematic and transparent manner.

Analysis

The selected studies were analyzed by extracting and comparing information related to the author(s), year of publication, educational level, research design, research instruments, and findings concerning the effectiveness of the ICARE learning model in improving students’ mathematical critical thinking skills. The coding, sorting, and categorization processes were conducted manually using Microsoft Excel to facilitate data management and analysis. Subsequently, a qualitative synthesis was performed to identify recurring patterns, similarities, and differences across the selected studies. The findings were then organized and interpreted to provide a comprehensive understanding of the effectiveness of the ICARE learning model in enhancing students’ mathematical critical thinking skills based on evidence from previous research.

Research Findings

The article search conducted through the Google Scholar database using the Publish or Perish application yielded 376 articles. After removing duplicate records, 373 articles remained. The articles were subsequently screened based on publication year and document type, resulting in 184 eligible records. A title and abstract screening process further reduced the number of potentially relevant studies to 45 articles. Following a full-text review and quality assessment,

10 articles met the inclusion criteria and were included in the final review. The article selection process is illustrated in Figure 1.

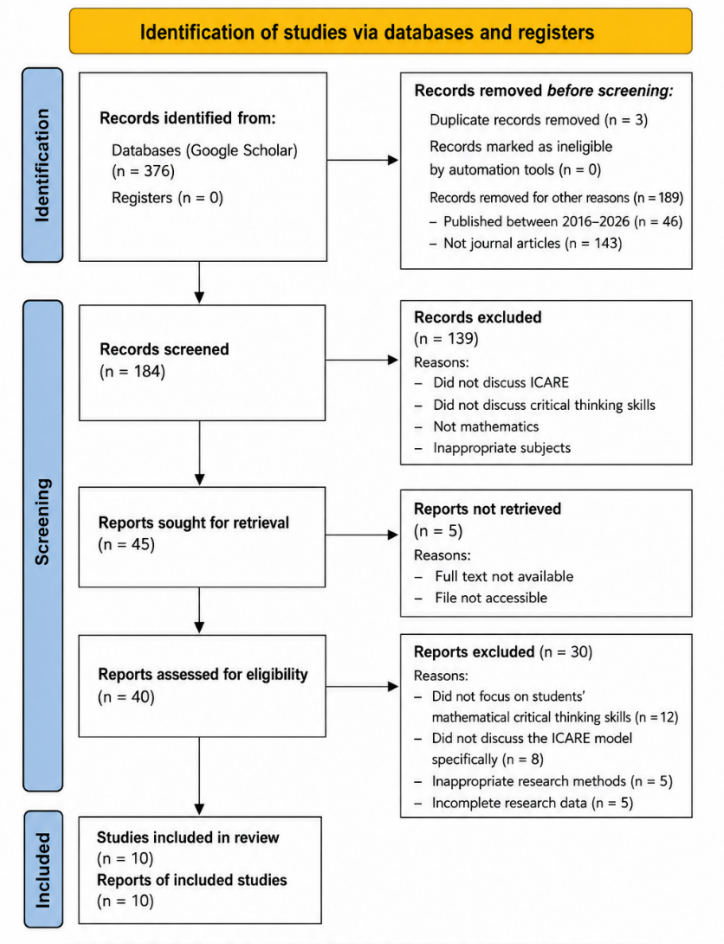

Figure 1. PRISMA Diagram of the Article Selection Process

Based on the studies that met the inclusion criteria, the general characteristics of the selected articles were identified, including the authors, year of publication, educational level, sample size, and research design. The results are presented in Table 3.

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Table 3. Characteristics of the Selected Studies

No	Author and Year	Educational Level	Sample Size	Research Method/Design
1	Prianto et al. (2025)	Grade 4 elementary school	39 students	Quasi-experimental (nonequivalent control group design)
2	Sari (2025)	Grade 10 senior high school	Not explicitly stated	Experimental (factorial experiment)
3	Jasmi & Yulkifli (2024)	Junior high school	Not explicitly stated	Research and Development (ADDIE)
4	Yulianto et al. (2024)	Junior high school	104 students	Quasi-experimental (2×2 factorial design)
5	Nasution et al. (2023)	Grade 7 junior high school	Not explicitly stated	Quasi-experimental
6	Rahmi et al. (2023)	Grade 10 senior high school	74 students	Quasi-experimental (nonequivalent comparison group design)
7	Rahmadhani et al. (2022)	Grade 8 junior high school	21 students	Descriptive qualitative study
8	Saputri et al. (2022)	Grade 10 senior high school	36 students	Classroom Action Research
9	Yenni et al. (2022)	Grade 10 senior high school	31 students	Pre-experimental (one-group pretest-posttest design)
10	Sa'diyah et al. (2021)	Grade 11 senior high school	21 students	Pre-experimental (one-group pretest-posttest design)

Table 3 shows that research on the effectiveness of the ICARE learning model in improving students' mathematical critical thinking skills has been conducted across various educational levels, including elementary school, junior high school, and senior high school. However, the majority of studies were conducted at the junior high school and senior high school levels, while research at the elementary school level remains limited. The sample sizes varied considerably, ranging from 21 to 104 participants, although several studies did not explicitly report the number of participants involved.

Regarding research methodology, quasi-experimental designs were the most frequently employed approach, including nonequivalent control group designs and factorial designs. Other research methods identified in the reviewed studies included pre-experimental designs, classroom action research, research and development (ADDIE), and descriptive qualitative research. These findings indicate that research on the ICARE learning model has primarily focused on examining its effectiveness in improving students' critical thinking skills in mathematics through experimental research designs.

The selected studies were further analyzed based on the research instruments used, indicators of mathematical critical thinking skills, and principal findings. The results are summarized in Table 4.

Table 4. Characteristics of Research Instruments and Findings

No	Author and Year	Research Instruments	Mathematical Critical Thinking Indicators	Main Research Findings
1	Prianto et al. (2025)	Tests and questionnaires	Interpretation, analysis, evaluation, inference, explanation, self-regulation	The ICARE model improves students' critical thinking skills with a higher N-Gain score compared to the control class.
2	Sari (2025)	Tests, self-efficacy questionnaires,	Interpretation, analysis, evaluation, inference, explanation, self-regulation	There is a significant difference in mathematical critical thinking skills between students who learn

No	Author and Year	Research Instruments	Mathematical Critical Thinking Indicators	Main Research Findings
		observations, documentation, ICARE LKK		using ICARE and those who follow a scientific approach.
3	Jasmi & Yulkifli (2024)	Validation sheet, practicality questionnaire, critical thinking questions	General critical thinking skills	ICARE-based e-modules effectively improve critical thinking skills with a moderate N-Gain.
4	Yulianto et al. (2024)	Pre-test and post-test essay questions	Interpretation, analysis, evaluation, inference, explanation	The I-CARE model supported by the Geometryx application has a significant effect on students' mathematical critical thinking skills.
5	Nasution et al. (2023)	Critical thinking and problem-solving ability tests	General mathematical critical thinking	The ICARE learning approach had a significant impact on students' critical thinking skills, at 59.4%.
6	Rahmi et al. (2023)	Pre-test and post-test and questionnaire	Problem analysis, evaluation, drawing conclusions	The Powtoon-based ICARE model improves students' mathematical critical thinking skills better than standard ICARE instruction.
7	Rahmadhani et al. (2022)	Interviews, observations, tests, and documentation	Interpretation, analysis, evaluation, drawing conclusions	The implementation of the ICARE model is able to improve students' critical thinking skills regarding function relations.
8	Saputri et al. (2022)	Critical thinking essay tests, observation sheets, student response questionnaires	Analysis, evaluation, inference	The ICARE model effectively enhances students' critical thinking and collaboration skills.
9	Yenni et al. (2022)	Multiple-choice pretest-posttest	Elementary clarification, basic support, inference, advanced clarification, strategy and tactics	The ICARE-U model effectively improves students' critical thinking skills with a moderate level of improvement (N-gain 0.48).
10	Sa'diyah et al. (2021)	Pretest-posttest tests and Rasch analysis	Basic clarification, bases for a result, interpretation, development clarification, supposition, and integration	The ICARE-R model is able to improve students' critical thinking skills with a moderate gain (N-gain 0.62).

According to Table 4, tests of mathematical critical thinking skills were the most frequently used instruments. These included pretest–posttest assessments, essay tests, and open-ended problem-solving tasks. In addition, several studies employed supporting instruments such as questionnaires, observation sheets, interviews, documentation records, validation sheets, and Rasch analysis to obtain more comprehensive data.

Regarding indicators of mathematical critical thinking skills, the most frequently studied indicators were interpretation, analysis, evaluation, inference, explanation, and conclusion drawing. Some studies also included indicators such as self-regulation, basic clarification, advanced clarification, and strategies and tactics. This indicates that studies on the ICARE model address not only fundamental critical thinking processes but also higher-order metacognitive and strategic thinking skills.

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Overall, the reviewed studies consistently reported a positive effect of the ICARE learning model on students' mathematical critical thinking skills. Most studies showed moderate to high improvements in critical thinking performance, as indicated by N-Gain scores, and statistically significant differences between students taught using the ICARE model and students taught using conventional or alternative instructional approaches. Furthermore, several studies revealed that integrating the ICARE model with educational media, such as the Geometryx app and Powtoon-based learning materials, resulted in more substantial improvements in students' mathematical critical thinking skills. These findings suggest that the effectiveness of the ICARE model can be enhanced when combined with interactive and technology-supported learning environments.

Next, the quality of the articles was assessed using five quality assessment criteria (Q1–Q5) to evaluate the methodological rigor of the selected studies. The quality assessment was conducted to ensure that the articles used in the research had clear research objectives, detailed research methods, appropriate research instruments, complete research results, and conclusions relevant to the research findings. The results of the quality assessment are presented in Table 5.

Table 5. Quality Assessment of Included Studies

No	Author and Year	Q1	Q2	Q3	Q4	Q5	Score	Quality Category
1	Prianto et al. (2025)	✓	✓	✓	✓	✓	5	Excellent
2	Sari (2025)	✓	✓	✓	✓	✓	5	Excellent
3	Jasmi & Yulkifli (2024)	✓	✓	✓	✓	✓	5	Excellent
4	Yulianto et al. (2024)	✓	✓	✓	✓	✓	5	Excellent
5	Nasution et al. (2023)	✓	✓	✓	✓	✓	5	Excellent
6	Rahmi et al. (2023)	✓	✓	✓	✓	✓	5	Excellent
7	Rahmadhani et al. (2022)	✓	✓	✓	✓	✓	5	Excellent
8	Saputri et al. (2022)	✓	✓	✓	✓	✓	5	Excellent
9	Yenni et al. (2022)	✓	✓	✓	✓	✓	5	Excellent
10	Sa'diyah et al. (2021)	✓	✓	✓	✓	✓	5	Excellent

Based on Table 5, all 10 studies received a score of 5 and were categorized as having excellent methodological quality. This indicates that all selected studies met the established quality criteria and provided sufficient methodological rigor for inclusion in this review. The consistently high quality of the selected studies strengthens the credibility of the findings synthesized in this review and supports the conclusion that the ICARE learning model has considerable potential to improve students' critical thinking skills in mathematics across a variety of educational contexts.

Discussion

Based on a synthesis of the 10 articles analyzed, the ICARE learning model demonstrates a positive impact on students' mathematical critical thinking skills at the elementary, junior high, and senior high school levels. Most of the reviewed studies reported moderate to high improvements in students' mathematical critical thinking skills, as reflected by N-Gain scores and statistically significant differences between students who learned through the ICARE model and those who experienced conventional instructional approaches. These findings are consistent with the studies conducted by Prianto et al. (2025), Yulianto et al. (2024), and Nasution et al. (2023), which demonstrated that the implementation of ICARE improved students' abilities in analysis, evaluation, interpretation, and inference. Collectively, these findings suggest that the ICARE model consistently contributes to the development of mathematical critical thinking skills.

The effectiveness of the ICARE model can be attributed to its structured learning stages, namely Introduction, Connection, Application, Reflection, and Extension. Each stage provides opportunities for students to engage in higher-order thinking processes. The Connection stage encourages students to relate new mathematical concepts to their prior knowledge and experiences, thereby supporting interpretation and analytical thinking. The Application stage allows students to apply mathematical concepts in problem-solving situations, which promotes evaluation and inference skills. Furthermore, the Reflection stage encourages students to examine their reasoning processes and evaluate the solutions they have produced. These characteristics are closely aligned with constructivist learning theory, which posits that knowledge is actively constructed through experience, interaction, and reflection. Consequently, the ICARE model provides a learning environment that supports active knowledge construction and critical engagement with mathematical concepts.

The synthesis also revealed variations in findings across the reviewed studies. For example, Rahmi et al. (2023) reported that Powtoon-assisted ICARE instruction produced better outcomes than conventional ICARE implementation, whereas Yulianto et al. (2024) found that the integration of the Geometryx application significantly enhanced students' mathematical critical thinking skills. Similarly, Jasmi & Yulkifli (2024) reported moderate improvements in critical thinking skills through the use of ICARE-based e-modules. These findings suggest that the effectiveness of the ICARE model is influenced not only by the instructional framework itself but also by supporting factors such as learning media, technological integration, research design, student characteristics, and educational level. Therefore, the successful implementation of ICARE may depend on how effectively the model is integrated with appropriate learning resources and instructional contexts.

Despite the predominantly positive findings, several limitations were identified across the reviewed studies. First, many studies involved relatively small sample sizes, which may limit the representativeness of the findings. Second, quasi-experimental designs were the most commonly used research approach, resulting in limited methodological diversity. Third, variations in the indicators used to measure mathematical critical thinking skills make direct comparisons across studies more challenging. In addition, most studies were conducted within a single school context, thereby limiting the generalizability of the findings to broader educational settings.

The findings of this review have important implications for mathematics education. The ICARE learning model may serve as an effective alternative instructional approach for enhancing students' mathematical critical thinking skills through active, contextual, and reflective learning experiences. Furthermore, this review contributes to the existing literature by providing a comprehensive synthesis of research on the effectiveness of the ICARE model across different educational levels and by identifying factors that influence the success of its implementation in mathematics education. These findings may serve as a foundation for future research examining the broader application of ICARE and its integration with innovative learning technologies and instructional media.

Conclusion

Based on the findings of this Systematic Literature Review involving 10 selected studies, the ICARE learning model demonstrates a positive impact on students' mathematical critical thinking skills across various educational levels. Improvements were consistently observed in students' abilities to analyze, interpret, evaluate, infer, and draw conclusions following the implementation of the ICARE model in mathematics learning. These positive outcomes can be attributed to the learning stages embedded within ICARE, which actively engage students in

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connecting concepts, solving problems, reflecting on their learning processes, and extending their understanding through contextual and reflective learning experiences. The findings also indicate that the effectiveness of the ICARE model is influenced by several factors, including instructional media, research design, student characteristics, and educational level. In particular, studies integrating ICARE with technology-based learning media reported more favorable outcomes in enhancing students' mathematical critical thinking skills. This review contributes to the existing literature by providing a comprehensive synthesis of empirical evidence regarding the effectiveness of the ICARE model and by identifying factors that influence its successful implementation in mathematics education. Despite these contributions, this review has several limitations. The literature search was conducted using only one database, Google Scholar, and the number of eligible studies included in the review was relatively limited. Furthermore, variations in research designs, instruments, and indicators used to measure mathematical critical thinking skills across studies made direct comparisons difficult. Therefore, future research is recommended to employ a wider range of databases, include a larger body of literature, and focus on more specific research designs and standardized indicators of mathematical critical thinking skills to generate more comprehensive and robust evidence.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Auhor Contributions

The contributions of the authors were distributed proportionally according to their respective roles. C.S.P. contributed 40% to the study, including conceptualization of the research, data collection, data analysis, and preparation of the initial manuscript draft. H.P. and Y.S. each contributed 30%, including concept development, methodological validation, manuscript revision, and refinement of the final version for publication.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author [C.S.P] upon reasonable request.

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