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Thinking Beyond the Equations: A Deep Dive into Reflective Thinking for Mathematics Learning

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Reflective thinking is a cognitive process that involves re-examining issues to overcome challenges in problem-solving. In the context of mathematics education, it serves not only as a tool for error correction but also as a means of fostering deeper conceptual understanding and self-regulation. This study aims to assess current research on reflective thinking within the field of mathematics education. To explore this, relevant keywords such as "reflective thinking" and "mathematics education" were used in literature searches. A systematic literature review (SLR) was conducted to enhance our understanding of the topic, focusing on articles indexed in the ERIC and Scopus databases. Following the PRISMA guidelines, we carefully evaluated 101 articles published between 2018 and 2024, eliminating duplicates and irrelevant content. Ultimately, 23 articles were selected based on predefined criteria. The findings reveal that reflective thinking is an ongoing and

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dynamic process that positively impacts academic achievement. The review highlights the significant role of reflective thinking in various areas, including problem-solving, creative idea generation, task completion, learning enhancement, decision-making, and the development of both systematic and conceptual skills. In conclusion, this study emphasizes the essential role of reflective thinking in mathematics education, underscoring its importance in improving educational practices and outcomes. Furthermore, reflective thinking not only enhances individual cognitive skills but also promotes collaborative and interactive learning environments, encourages reflective teaching practices among educators, and strengthens lifelong learning dispositions, all of which are crucial for holistic educational development.

Introduction

The process of solving mathematical problems can benefit from the application of reflective mathematical thinking (Toraman et al., 2020). Reflective thinking skills enable students to effectively address and solve a range of challenges encountered in the realm of mathematics learning (Dubinsky, 2002). Reflective thinking entails a sequence of thoughts deemed to be of optimal quality (Dewey, 1933). It encompasses steps like comprehending the problem, conducting research, and gathering information to facilitate the problem-solving process. Reflective thinking is characterized as a hallmark of sound cognitive processes (Paul, 1990; Rodgers, 2002), thereby necessitating its cultivation within educational contexts. Incorporating reflective mathematical thinking during the learning journey can guide the structure of problem-solving approaches, contributing to more effective resolutions (Baron, 1981). The development of reflective mathematical thinking skills is aimed at delving deeper into mathematical matters and observing the progression of solution-finding processes.

Understanding reflective thinking in the context of mathematics education is of significant importance. Earlier research highlights the crucial role of reflective thinking skills in the field of mathematics education (Dervent, 2015; Kholid et al., 2020; Minott, 2011; Saracoglu, 2022; Toraman et al., 2020). To foster continuous learning experiences for both educators and learners, the development of reflective thinking skills must be emphasized within mathematics education. The application of reflective thinking in mathematical problem-solving can stimulate students' curiosity (Egmir & Ocak, 2020; Katrancı & Şengül, 2020). Furthermore, reflective thinking creates an environment where students can make thoughtful and reasoned decisions when faced with complex challenges (Procter, 2020). Additionally, it supports the development of conceptual understanding and abstraction, leading to innovative problem-solving (Dervent, 2015).

Reflective thinking plays a crucial role in the problem-solving process, particularly for prospective educators who apply mathematical concepts and knowledge to find solutions. As students engage with mathematical problems, they are expected to develop their ability to use reflective thinking throughout their learning journey. Mastery of reflective mathematical thinking is closely linked to improved problem-solving skills, which can be enhanced through structured and conceptual reflection (Yasin et al., 2020). In addition to refining reflective thinking, students are encouraged to strengthen their mathematical problem-solving abilities, especially within the field of mathematics education. Proficiency in reflective thinking aids students in improving their skills and knowledge, enabling them to address challenges in both educational and community contexts (Demir, 2015; Kalelioğlu, 2015).

There have been Systematic Literature Review (SLR) investigations into reflective thinking predominantly outside the domain of mathematics education. For instance, SLRs explore reflective thinking habits among school principals concerning ethical leadership and decision-making (Cornito & Caingcoy, 2021). The role of reflection and reflective practice in health professional education has been evaluated (Liao & Wang, 2019; Mann et al., 2009). Additionally, the correlation between learning achievement and reflective thinking has been examined in various contexts, but not with a specific focus on mathematics education (Chamdani et al., 2022). While some studies have investigated reflective thinking in other fields, there remains a significant gap in research that focuses on reflective thinking within mathematics education. Although systematic reviews have been conducted in other areas, they do not fully address how reflective thinking impacts mathematical problem-solving, teacher preparation, and student learning in this specific field. This research aims to fill this gap by examining the role of reflective thinking within mathematics education, addressing the existing deficiencies in the literature, and offering insights into how reflective thinking can enhance mathematics teaching and learning.

Literature review

Reflective thinking has long been recognized as a fundamental cognitive process in education, with Dewey's (1933) seminal work establishing its role in meaningful learning (Rodgers, 2002). While extensively studied in general education contexts, its application within mathematics education remains underexplored (Dervent, 2015; Kholid et al., 2020). The current body of research primarily focuses on generic frameworks of reflective thinking, often failing to address the unique cognitive demands of mathematical reasoning and problem-solving (Baron, 1981; Dubinsky, 2002). This limitation becomes particularly apparent when considering how reflective thinking interacts with mathematical processes such as abstraction, logical proof construction, and iterative solution refinement (Tall, 2002; Vinner, 2002).

Previous research on reflective thinking in mathematics education can be broadly categorized into three main areas (Taggart & Wilson, 2005). First, teacher-focused studies have examined how reflective thinking influences instructional practices and professional development among mathematics educators (Minott, 2011; Zwozdiak-Myers, 2018). Second, cognitive process studies have explored how students engage in reflective thinking during mathematical problem-solving activities (Kholid et al., 2022a; Orakcı, 2021). Third, instrument development research has produced various tools to measure reflective thinking, though these frequently lack specificity to mathematical contexts (Kizilkaya & Askar, 2009; Zehavi & Mann, 2005). While these studies provide valuable insights, they collectively reveal significant limitations that warrant further investigation (Broza et al., 2022; Erdoğan, 2020).

Several notable gaps emerge from the existing literature (Gourlet et al., 2016). A primary concern is the lack of domain-specific frameworks that adequately adapt reflective thinking models to mathematical contexts (Hong & Choi, 2011). While theoretical models such as Dewey's phases of reflection and Taggart and Wilson (2005) reflective thinking pyramid offer valuable foundations, they have not been sufficiently tailored to address the full spectrum of mathematical thinking processes (Leung & Kember, 2003). This is particularly evident in the limited attention given to higher-order reflective processes, such as dialectical reflection, which involves evaluating and synthesizing multiple solution strategies (Sa'dijah et al., 2021).

Methodological limitations also characterize much of the current research (Okoli & Schabram, 2010). Many studies rely heavily on quantitative survey methods that capture self-reported

reflective thinking tendencies rather than actual problem-solving behaviors (Akdemir, 2018; Toraman et al., 2020). This approach provides limited insight into how reflective thinking manifests during authentic mathematical activities (Hidajat & Sa'dijah, 2019). Additionally, the literature shows a striking absence of longitudinal studies that track the development of reflective thinking skills in mathematics learners over time (S. Setiyani et al., 2024).

The existing research also exhibits significant demographic and contextual limitations (Cornito & Caingcoy, 2021). Studies tend to concentrate on specific populations, with particular emphasis on secondary school students and mathematics teachers, while largely neglecting elementary school learners (Deringöl, 2019; Sarican & Akgunduz, 2018). Furthermore, the geographic distribution of research raises important questions about cultural influences on reflective thinking in mathematics (Aldahmash et al., 2021; Yasin et al., 2020).

Practical implementation represents another critical gap in the literature (Hendriana et al., 2019). While numerous studies have established the benefits of reflective thinking for mathematical learning, few have translated these findings into actionable classroom strategies (Ramdani et al., 2019; Syamsuddin et al., 2023). Similarly, the potential role of technology in fostering reflective thinking within mathematics education remains largely unexplored (Gökçe & Yenmez, 2023).

To address these gaps, this study maintains important conceptual frameworks while contextualizing them within mathematics education (Ball & Bass, 2002). Table 1 presents indicators of reflective thinking specifically adapted for mathematical contexts, mapping reflective components to their mathematical applications (Zehavi & Mann, 2005). Figure 1 illustrates the reflective thinking pyramid, demonstrating how different levels of reflection contribute to mathematical understanding (Taggart & Wilson, 2005). These visual representations serve to bridge the gap between theoretical models and their practical application in mathematics education (Ng & Tan, 2006).

Table 1. Indicator reflective thinking

Component (Zehavi & Mann, 2005)	**Indicators** (Sa'dijah et al., 2021)
Techniques	1. Finding how to understand the information. 2. Finding how to understand the question. 3. Selecting an effective and efficient solution
Monitoring	1. Monitoring the steps of the solution. 2. Monitoring the answer whether correct or not.
Insight	1. Being ready to correct wrong answers. 2. Understanding how to avoid difficulties
Conceptualization	1. Thinking about an alternative solution 2. Relating concepts to question

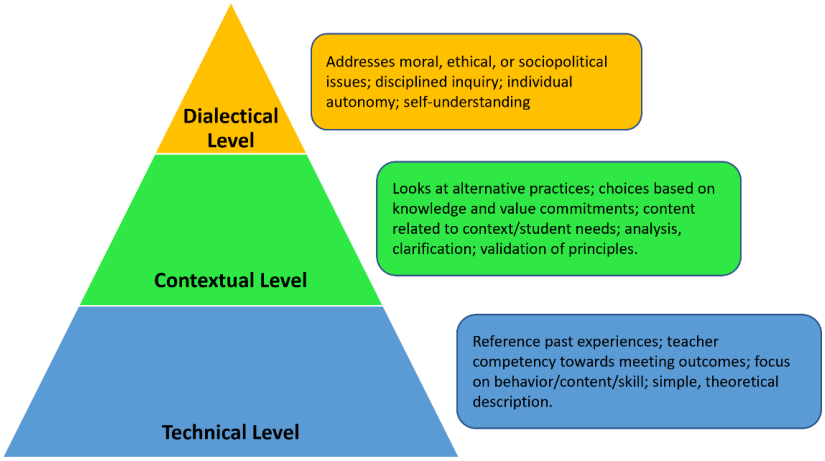

Figure 1. The reflective thinking pyramid (Adapted from Taggart & Wilson , 2005) by the researcher

This literature review highlights the need for more nuanced investigations of reflective thinking in mathematics education (Procter, 2020). By identifying these research gaps, the current study aims to provide a foundation for future research that can develop more sophisticated frameworks, methodologies, and practical applications of reflective thinking in mathematics teaching and learning (Prediger, 2005). The preservation of these visual frameworks ensures continuity with existing literature while allowing for their adaptation to the specific demands of mathematics education (Dreyfus, 2002).

Research questions

In this investigation, reflective thinking is characterized as the engaged, consistent, and meticulous examination of beliefs or knowledge forms (Dewey, 1933). This form of thinking positions both educators and learners within a constructivist and inquiry-driven framework during the educational journey. Earlier studies in the field of reflective thinking have explored various dimensions, including its role in problem-solving, teacher development, and student learning. Recent systematic reviews emphasize how reflective thinking contributes to academic achievement and critical thinking skills, highlighting its effectiveness in both school and higher education contexts (Sudirman et al., 2024; Titus & Muttungal, 2024). These studies have provided a foundation for understanding how reflective thinking can impact educational outcomes across different disciplines. Flora (2023) also underscores the importance of reflective thinking in teacher development, particularly in improving pedagogical practices and classroom management. Drawing from these prior scholarly inquiries, this research endeavor seeks to delve into the realm of reflective thinking within mathematics education through a conceptual framework encompassing factors such as distribution and demographics, research approaches, participant attributes, and the central themes of studies associated with reflective thinking. The research inquiries outlined in Table 2 encapsulate the objectives and achievements of this study.

Table 2. Research questions

Code	Research questions (RQ)	Motivation
RQ1	How has articles on research on reflective thinking in mathematics education been distributed in the last five years?	This question seeks to identify studies on reflective thinking that have been carried out in terms of the year and place of study. The year and demographics of the selected studies will provide an overview of the development of the reflective thinking studies that have been carried out and predict what still needs to be investigated further.
RQ2	What research methodologies are used in the existing literature?	RQ2 seeks to reveal the most common methodology used concerning reflective thinking. How the practice of reflective thinking fits into the teaching and learning process will be discussed in this section.
RQ3	How about participant characteristics?	Participant characteristics in selected studies will provide an overview of the effectiveness and purpose of reflective thinking at the formal school level.
RQ4	What trends are being studied in research on reflective thinking?	This research question seeks to uncover other topics that are often researched together with reflective thinking. This can provide how far reflective thinking is related to other concepts.
RQ5	How does reflective thinking play a role in influencing problem-solving in mathematics classroom?	This research question will focus on the significant role of reflective thinking in enhancing problem-solving in mathematics classroom.

Method

Research Design

The current study employed a systematic literature review (SLR) approach to examine the field of reflective thinking in mathematics. The primary objective of this study was to synthesize existing scholarly works concerning the ability to engage in reflective mathematical thinking, guided by four distinct goals: (1) to analyze the distribution of mathematical reflective thinking skills from 2018 to 2024, (2) to assess the prevalence of mathematical reflective thinking skills across various countries, (3) to examine the methodologies used and research outcomes discussed in the literature, and (4) to identify the key themes and patterns within the existing body of work.

The selection of the SLR methodology for this investigation was informed by its ability to facilitate a transparent assessment of research strengths and limitations. In general, SLR studies provide a comprehensive view of a specific research domain by consolidating knowledge, identifying research gaps, and assessing the current state of understanding (Xiao & Watson, 2019). This approach ensures a rigorous evaluation of the literature and helps to maintain the quality of scholarly reporting. To uphold this standard, the literature underpinning this study was evaluated following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines, which are widely recognized for their role in ensuring methodological transparency and consistency (Page et al., 2021).

Identification

The search strategy employed in this study involved the use of two databases: SCOPUS and ERIC. The search terms used in both databases included combinations of keywords, such as "reflective thinking" and "mathematics education," along with their synonyms and Boolean operators. For SCOPUS, the search query was ("reflective thinking" AND "mathematics education") OR ("reflective thinking" AND "mathematics"). Similarly, for ERIC, the query used was ("reflective thinking" AND "mathematics education") OR ("reflective thinking" AND "mathematics"). These keywords and Boolean operators ensured a comprehensive search of relevant studies related to the research question.

Screening

Figure 2 illustrates the systematic approach employed in this research to narrow down the selection of articles, culminating in a final tally of 101 pieces. The screening process commenced with an initial evaluation of article titles and abstracts, followed by a more comprehensive assessment of full-text content. Articles failing to fulfill the predetermined inclusion criteria were eliminated.

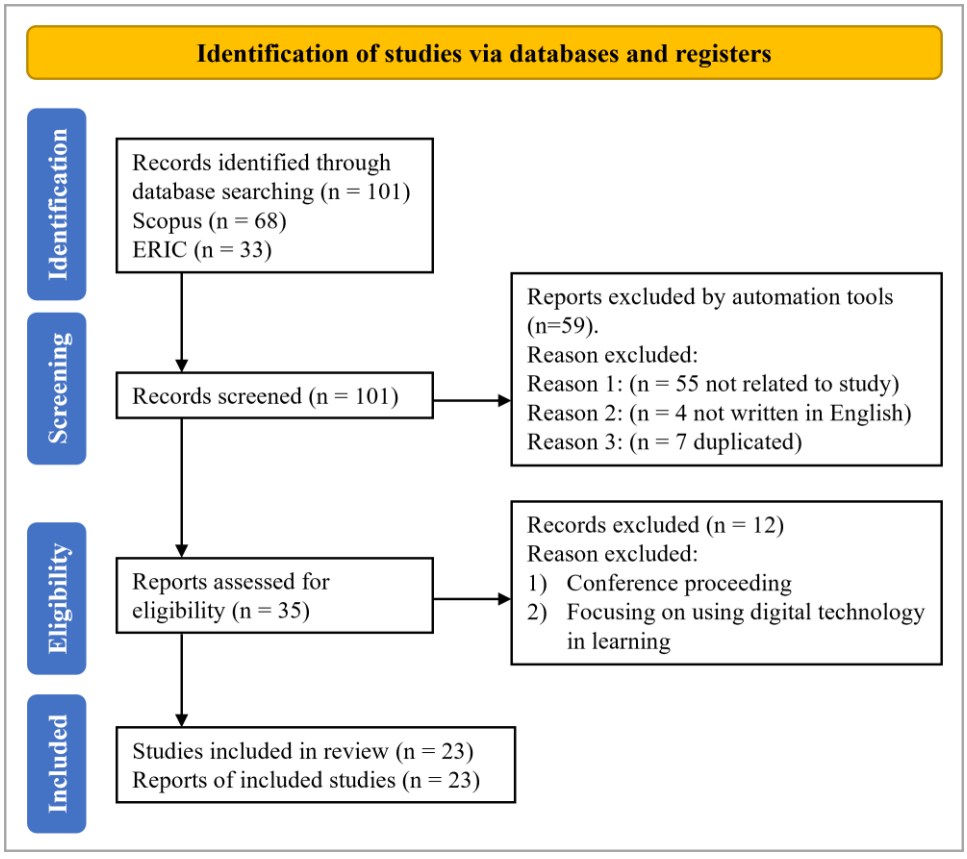

Figure 2. PRISMA flow diagram

To uphold the dependability and precision of the screening procedure, a randomized subset comprising 10 articles was chosen from the pool of 101 articles and subjected to validation by the authors. Notably, the agreement between raters was notably high, demonstrated by the detailed discussion of two papers out of the 10, while one paper was excluded due to two out of three reviewers concurring that it failed to meet the predetermined inclusion criteria for the study. In order to sustain the robustness and meticulousness of the research, the assessment criteria for the articles' quality were established in accordance with the guidelines formulated

by Gough (Gough, 2007), which are presented in Table 3.

Table 3. Weight of evidence judging criteria

Level 1-4	Methodology quality	Methodology relevance	Topic relevance
1. Excellent	Excellent research approach and method quality	Excellent use of the research design to answer RQs	Clearly defined research answers Referred to ethics concerning children
2. Good	Good relationship multiple review elements	Sound use of research design	Useful, relates to research questions
3. Satisfactory	It appears logical and relatable	Broadly matched to elements of research questions	Broadly relevant to research questions
4. Inadequate	Research design or analysis not clearly stated	Not suited to research questions	Did not answer research questions

Eligibility

This review aimed to investigate the attributes of reflective thinking skills, and the instructional strategies employed to cultivate them. The systematic data generation process is outlined in Figure 2. To ensure the selection of pertinent studies, specific criteria for inclusion were established, as detailed in Table 4. Two electronic databases were utilized by the researchers as sources of data. A search query was devised to identify keywords pertinent to recent literature spanning the last five years. The assessment of article quality hinged on criteria devised by Gough (Gough, 2007), as outlined in Table 3. The outcomes of the screening procedure are graphically presented in Figure 2.

Inclusion/exclusion criteria

This present literature review has intentionally omitted investigations concentrating on the utilization of digital technology in the learning process. This choice was grounded in the researchers' aim to foster learning settings that emphasize communication, eye contact, and immediate interaction, aspects that diverge from the application of digital technologies in learning. Furthermore, this study has exclusively considered references available through open-access channels. The primary aim of this literature review is to procure insights that enrich the delineation of reflective thinking skills. To accomplish this objective, the researchers have concentrated their efforts on scrutinizing studies conducted within the timeframe spanning 2018 to 2024, as temporal limitations necessitated an up-to-date examination of the available literature. The criteria applied to determine the inclusion or exclusion of studies in this review are concisely summarized in Table 4.

Table 4. Inclusion/exclusion criteria

Criterion type	Inclusion	Exclusion
Publication	2018-2024	Before 2018
Quality Assurance	Studies published in peer-reviewed journals	Not published in peer-reviewed journals
Language	English	Non-English text
Topic	Reflective thinking	
Geographical location	Worldwide studies	
Digital technology		Exclude with reason

Bias assessment

To secure the precision and dependability of the data, the authors of this review engaged in independent coding of the content extracted from the chosen set of 20 articles. Subsequently,

these coded data were subjected to thorough discussion and assessment during several meetings. Furthermore, to ascertain the congruence between the coders, a random subset of ten articles was selected and subjected to separate coding by both authors. The resultant Cohen's Kappa value of 0.545 ($p < 0.01$) indicated a moderate level of agreement, in line with the criteria outlined by Viera & Garrett (Viera & Garrett, 2005). In instances where disparities emerged in the coding outcomes, the authors collaboratively reviewed the data to ensure consistency and congruence.

Data Analysis

The information extracted from each study was systematically recorded in an Excel spreadsheet. This record encompassed vital particulars like the author, country, year, attributes of participants, research inquiries, methodologies, and outcomes. To structure and amalgamate the pertinent data discoveries, two distinct types of data analysis methodologies were implemented. Primarily, a descriptive analysis was undertaken to compile information regarding references, the central focus of the studies, crucial concepts, and the contextual backdrop. Subsequently, a thematic analysis was executed to derive codes and categories from the amassed data sources.

Results And Discussion

Findings

The review of literature employed a stringent set of criteria, leading to a reduction in the initial pool of 101 scholarly articles to a refined selection of 23 papers that underwent comprehensive full-text scrutiny. The ultimate compilation of the review comprised these meticulously chosen 23 articles, meticulously filtered in accordance with the criteria expounded in Table 4. The primary thrust of this study resides in the examination of the capacity for reflective thinking within the domain of mathematics, a pivotal facet encompassing the questioning of personal beliefs, values, and presumptions. The significance of reflective thinking within the realm of mathematics education is extensively deliberated upon in this comprehensive literature review. For a more intricate depiction of the screening procedure, kindly refer to Figure 2, which visually presents a lucid representation of the PRISMA flowchart. The results were reported in accordance with the RQ.

RQ1: How has articles on research on reflective thinking in mathematics education been distributed in the last five years?

The first research inquiry pertains to the temporal aspect of research conduct. The distribution of studies exploring reflective thinking exhibits a discernible disparity, as visually represented in Figure 3. In 2018, two investigations emerged from Turkey (Akdemir, 2018; Sarican & Akgunduz, 2018). Subsequently, in 2019, a total of nine studies surfaced from both Indonesia and Turkey (Deringöl, 2019; Erdogan, 2019; Hendriana et al., 2019; Hidajat & Sa'dijah, 2019; Ramdani et al., 2019). The year 2020, the most prolific in terms of studies on reflective thinking, featured eight inquiries (constituting 40% of the total) hailing predominantly from Indonesia and Turkey (Egmir & Ocak, 2020; Erdoğan, 2020; Fitriati et al., 2020; Kholid et al., 2020; Ozyildirim-Gumus & Ozyildirim, 2020; Syamsuddin et al., 2020; Toraman et al., 2020; Yasin et al., 2020). In the year 2021, only one study investigating reflective thinking emerged, originating from Spain (Aldahmash et al., 2021). Furthermore, for the year 2022, a total of four studies were conducted, emanating from Indonesia, Turkey, and Israel (Broza et al., 2022; Kholid et al., 2022a; Saracoglu, 2022; Setiyani et al., 2022). In 2023,

there were two articles published (Gökçe & Yenmez, 2023; Syamsuddin et al., 2023), while in 2024, there was one article (Setiyani et al., 2024).

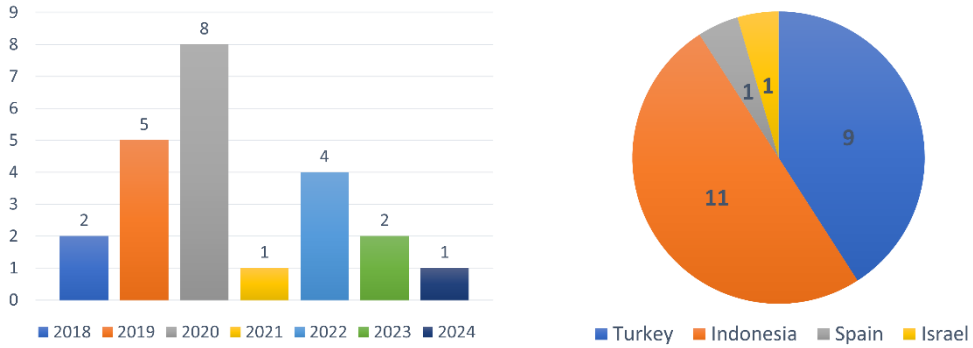

Figure 3. Selected study year and demographics

RQ2: What research methodologies are used in the existing literature?

The second research question pertains to the employed research methodology, encompassing qualitative research, quantitative research, and Research and Development (R&D). Figure 4 visually presents the distribution of the research methodologies adopted. This representation underscores that quantitative research constitutes the prevailing methodology in investigations pertaining to reflective thinking, accounting for 52% of the studies conducted (Akdemir, 2018; Broza et al., 2022; Deringöl, 2019; Egmir & Ocak, 2020; Erdogan, 2019; Erdoğan, 2020; Fitriati et al., 2020; Ozyildirim-Gumus & Ozyildirim, 2020; Saracoglu, 2022; Sarican & Akgunduz, 2018; Toraman et al., 2020; Yasin et al., 2020). Qualitative research methodologies constitute 30% of the studies (Aldahmash et al., 2021; Hidajat & Sa'dijah, 2019; Kholid et al., 2020, Kholid et al.,2022b; Setiyani et al., 2022; Setiyani et al., 2024; Syamsuddin et al., 2020), whereas the adoption of Research and Development (R&D) methodologies is observed in 13% of the studies (Hendriana et al., 2019; Ramdani et al., 2019; Syamsuddin et al., 2023). Additionally, one study employed a mixed method approach (Gökçe & Yenmez, 2023).

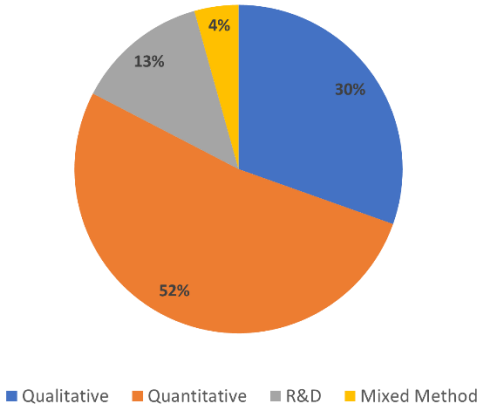

Figure 4. Selected paper research methodology

RQ3: How about participant characteristics?

The third research question pertains to the attributes of research participants. Figure 5 visually portrays the distribution of participant characteristics across studies focusing on reflective thinking. Out of the total, ten investigations (representing 44% of the corpus) were conducted with secondary school students as the focal research subjects (Akdemir, 2018; Erdogan, 2019; Fitriati et al., 2020; Hendriana et al., 2019; Hidajat & Sa'dijah, 2019; Ozyildirim-Gumus & Ozyildirim, 2020; Ramdani et al., 2019; Setiyani et al., 2024; Toraman et al., 2020; Yasin et al., 2020). Five studies concentrated on elementary school students (Deringöl, 2019; Egmir & Ocak, 2020; Gökçe & Yenmez, 2023; Sarican & Akgunduz, 2018; Syamsuddin et al., 2023). Notably, seven studies (constituting 35%) targeted prospective mathematics teachers as their research participants (Broza et al., 2022; Erdoğan, 2020; Kholid et al., 2020; Saracoglu, 2022; Setiyani et al., 2022; Syamsuddin et al., 2020). Singularly, one study centered on a mathematics teacher as the participant (Aldahmash et al., 2021).

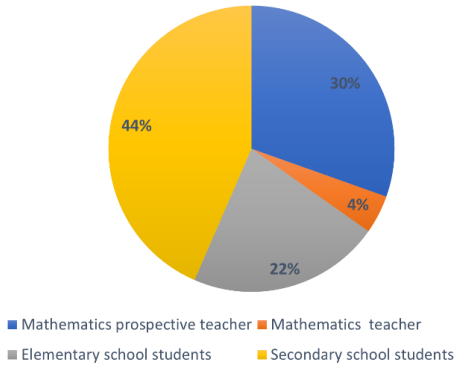

Figure 5. Participant characteristics selected papers

RQ4: What trends are being studied in research on reflective thinking?

Research inquiry four pertains to prevalent trends and focal points within the domain of reflective thinking. This study identified a multitude of investigations concentrating on the capacity for reflective thinking. Among these, the majority of research endeavors center around reflective thinking's application to problem-solving abilities, representing 52% of the total studies (Akdemir, 2018; Aldahmash et al., 2021; Egmir & Ocak, 2020; Gökçe & Yenmez, 2023; Kholid et al., 2020, Kholid et al., 2022b; Ozyildirim-Gumus & Ozyildirim, 2020; Ramdani et al., 2019; Sarican & Akgunduz, 2018; S. Setiyani et al., 2024; Syamsuddin et al., 2020; Toraman et al., 2020; Yasin et al., 2020). Moreover, two studies delve into critical thinking skills (Broza et al., 2022; Erdoğan, 2020) and the development of teaching materials (Hendriana et al., 2019; Syamsuddin et al., 2023). Furthermore, there exists a solitary study dedicated to each of the subsequent reflective thinking focal points: mathematical task analysis (Fitriati et al., 2020), models of cooperative learning (Erdogan, 2019), achievements in mathematics education (Deringöl, 2019), inquiry skills, and self-efficacy (Saracoglu, 2022), disposition toward mathematics (Setiyani et al., 2022), cognitive style (Syamsuddin et al., 2020), metacognitive awareness (Toraman et al., 2020), and the aptitude for probabilistic thinking (Ozyildirim-Gumus & Ozyildirim, 2020).

Figure 6. Trends and research focus related to reflective thinking

RQ5: How does reflective thinking play a role in influencing problem-solving in the classroom?

There are 12 studies spotlighting the connection between reflective thinking and problem-solving, as depicted in Figure 6. The amalgamation of findings through this SLR substantiates the substantial role of reflective thinking in shaping problem-solving competencies within educational settings (Akdemir, 2018; Aldahmash et al., 2021; Egmir & Ocak, 2020; Gökçe & Yenmez, 2023; Kholid et al., 2020, Kholid et al., 2022b; Ozyildirim-Gumus & Ozyildirim, 2020; Ramdani et al., 2019; Sarican & Akgunduz, 2018; S. Setiyani et al., 2024; Syamsuddin et al., 2020; Toraman et al., 2020; Yasin et al., 2020). Reflective thinking not only equips students to scrutinize and assess their cognitive processes when confronted with challenges but also empowers them to surmount perplexities and complexities in the realm of problem-solving. This style of critical thinking cultivates the formulation and evaluation of strategies, thereby enhancing the quality of decision-making during problem-solving pursuits. Reflective thinking serves to attenuate vulnerabilities and refine solutions, ultimately engendering more robust problem-solving outcomes. It empowers students to steer their own learning odyssey, fostering vigorous engagement when grappling with intricate problems.

In the context of mathematics and STEM education, reflective thinking emerges as a potent catalyst for enhanced problem-solving, prodding students to interrogate, contemplate, and assess. Despite these conspicuous advantages, certain students tend to adopt a passive stance towards reflective thinking, prioritizing correct answers over the comprehension of problem objectives. As a result, interventions geared toward enhancing students' reflective thinking competencies are imperative for fostering more effective problem-solving dynamics in educational settings (Kholid et al., 2022b; Yasin et al., 2020).

Moreover, reflective thinking exerts substantial influence on pedagogy, furnishing educators with the means to fine-tune their instructional strategies to augment student learning and comprehension, thereby fostering a more conducive learning milieu (Aldahmash et al., 2021). However, it is prudent to acknowledge that the impact of reflective thinking can manifest diversely contingent on the pedagogical context and teaching methodologies employed (Sarican & Akgunduz, 2018). Thus, further inquiry is warranted to delve into the intricacies of reflective thinking and its capacity to catalyze transformative shifts in classroom problem-solving paradigms. The taxonomy of reflective thinking encompasses productive, connective, and clarificative modalities, each bearing distinctive strategies for surmounting intricacies within

the ambit of problem-solving. The cultivation of reflective thinking skills holds particular relevance for students with modest mathematical proficiencies.

Discussion

Distribution of Research Articles on Reflective Thinking in Mathematics Education in the Last Five Years

Our findings indicate that the majority of studies were conducted in 2020, followed by 2019, 2022, 2018, 2023, 2021, and 2024, as depicted in Figure 3. In terms of the geographic origins of authors contributing to the selected articles, our results reveal that a significant proportion of research concerning reflective thinking skills emanates from Turkey and Indonesia, while others originate from Spain and Israel. The graphs representing research trends pertaining to reflective thinking over the past seven years within the chosen studies exhibit a pattern of fluctuation and instability.

These findings highlight a gap in the consistency and geographical representation of research on reflective thinking in mathematics education. The fluctuating trends could indicate a lack of sustained interest or funding for reflective thinking studies over the years, especially in certain regions. The findings suggest that while some countries, such as Turkey and Indonesia, have a strong focus on this area, the literature could benefit from more consistent contributions across diverse regions to provide a more holistic understanding of reflective thinking in various educational contexts. This pattern of fluctuation can be attributed to the perception of reflective thinking as a multifaceted process integrating cognitive skills, experiential insights, and discernment. This complexity may explain the inconsistency in research output, as it prompts individuals to apply reflective thinking within the context of learning and problem-solving endeavors (Rodgers, 2002). Bridging this gap involves a more focused, longitudinal examination of reflective thinking across different educational systems to better understand its evolving role.

Reflective thinking tends to be relatively infrequent due to its non-spontaneous nature in everyday situations, requiring dedicated time and effort for active contemplation (Gelter, 2003). Nonetheless, it is imperative for both students and educators to engage in introspection, examination, inquiry, and contemplation regarding their acquired knowledge. Within this framework, the acts of reflection, inquiry, and skepticism assume an essential role (Changwong et al., 2018). To bridge the gap, it is crucial to further investigate how reflective thinking practices are integrated into different educational environments and curricula, especially in regions where it is less prevalent.

Research Methodologies in the Existing Literature on Reflective Thinking

Addressing the second research question, we found that the predominant research method in the investigated studies concerning reflective thinking is quantitative, followed by qualitative research, Research and Development (R&D), and Mixed Methods. Both quantitative and qualitative approaches have been employed to explore how reflective thinking is integrated into mathematics teaching and learning processes, as well as to cultivate the associated skills.

Among the selected studies, quantitative methods were used to reveal reflective thinking skills among students, prospective teachers, and educators. These methods were also applied to cooperative learning, problem-solving, critical thinking, probabilistic thinking, mathematical academic achievement, metacognition, and self-efficacy. The findings from quantitative studies indicate that reflective thinking originates from individual confusion, requiring the integration

of knowledge, experience, and attitudes. This highlights the cognitive complexities involved in reflective thinking and suggests a need for further research to explore these cognitive processes in greater depth.

Conversely, qualitative methods describe reflective thinking processes in solving mathematical problems by students and prospective teachers, as well as in educators' professional activities in classrooms. R&D was conducted to design teaching materials promoting reflective thinking. Additionally, one study employed a mixed-method approach to integrate both qualitative and quantitative data, providing a comprehensive analysis of reflective thinking. The combination of these approaches offers a fuller understanding of reflective thinking, capturing both observable behaviors and underlying cognitive processes.

These findings help bridge the gap by providing a more comprehensive picture of how reflective thinking can be assessed and developed in mathematics education. Quantitative research, while accommodating small sample sizes with significant inter-individual variability, offers insights into broader patterns in reflective thinking. However, qualitative insights into students' and educators' personal experiences provide rich, detailed data that quantitative methods alone cannot capture. Therefore, a more integrated approach—combining both qualitative and quantitative methods—seems necessary to fully understand the complex nature of reflective thinking. This integrated approach bridges the gap in literature where research often isolates these methodologies, providing a clearer understanding of the multifaceted nature of reflective thinking.

Generally, most studies on reflective thinking in mathematics education argue that quantitative methods enable the evaluation of unobservable cognitive processes, particularly those residing in the subconscious (Barnham, 2015). The variation in methodologies and findings across studies suggests that more research is needed to explore which methods are most effective in capturing the nuances of reflective thinking and to bridge the existing gaps in methodological approaches. By addressing these gaps, future research can offer more robust insights into how reflective thinking can be better understood and applied in mathematics education.

Participant Characteristics in Reflective Thinking Research

Within the reviewed studies, participants encompassed school students among the researched cohorts. The cultivation of reflective thinking abilities not only facilitates profound learning but also equips students, aspiring educators, and teachers with distinct skills to foster critical perspectives and expertise within their professional realms. While numerous studies focus on reflective thinking among school-age children, there is a notable gap in research addressing prospective teachers and teachers engaged in mathematics education. This absence limits the applicability of insights on reflective thinking, especially when derived primarily from studies involving younger students, and underscores the need for further exploration of reflective thinking in adult education settings.

Reflective thinking in teachers and prospective teachers necessitates the utilization and refinement of their emotional competencies to enhance pedagogical practices (Minott, 2011). Highlighting the importance of instilling reflective thinking in teacher candidates and educators, such an approach (Clarà et al., 2019) helps prevent the perpetuation of conventional educational paradigms in school environments. By addressing this gap, the current study contributes to the body of literature by emphasizing the role of reflective thinking in improving pedagogical strategies and fostering professional growth among educators.

The integration of reflective thinking within educational contexts significantly contributes to the maturation of teachers' professional aptitude (McLeod et al., 2020; Zwozdiak-Myers, 2018). This is especially crucial in the development of higher-order thinking skills (HOTS), which directly align with reflective thinking competencies and teacher efficacy (Muntazhimah et al., 2021). By examining how reflective thinking is applied among both students and educators, the findings from this study bridge the gap in understanding the role of reflective practice across various educational stages and professional contexts.

Orakcı (2021) underscores the success of the learning process through real-life reflection, positing that, within a constructivist framework, one of the foremost learning goals is the realization of reflective practice. In this context, teachers who engage in reflective thinking not only foster students' reflective capacities but also enhance their own professional development. Educators with effective communicative attributes during the learning journey play a pivotal role in nurturing comprehensive student learning experiences, subsequently fostering the development of students' reflective thinking proficiencies. Teachers who actively engage in reflective thinking exhibit open-mindedness and are adept at formulating and evaluating instructional strategies through self-assessment, all while prioritizing their ongoing development and lifelong learning. These findings highlight the need for more emphasis on reflective thinking in teacher training programs and suggest that its integration can significantly benefit both students and educators.

Trends Explored in Research on Reflective Thinking

Most of the scrutinized studies center on the development of reflective thinking skills, particularly in relation to problem-solving capabilities. Experts define reflective thinking as a cognitive process wherein individuals amalgamate previously acquired knowledge with fresh information to tackle novel challenges (Kholid et al., 2020; Miettinen, 2000; Procter, 2020). During the resolution of novel problems, students engage in reflective consideration of prior knowledge, linking it to newfound insights to determine effective pathways toward solutions and conclusive outcomes. This approach, as articulated by the National Council of Teachers of Mathematics (NCTM, 2000), aims to cultivate systematic thought processes among students, encouraging them to methodically explore potential solutions and outcomes while organizing diverse knowledge and experiences.

These findings bridge a gap in the literature by highlighting how reflective thinking contributes to the development of problem-solving strategies in mathematics. Previous studies have often focused on problem-solving or reflective thinking separately, but our findings show that the integration of reflective thinking into problem-solving enhances students' ability to approach challenges in a more structured and insightful way. This connection is particularly important in the context of mathematics education, where complex problem-solving is a key component of student success.

Regarding the interplay of reflective and critical thinking skills, reflective thinkers attain awareness and control over their learning process by actively discerning existing knowledge, identifying gaps, and devising strategies for bridging them (Afshar & Rahimi, 2016). The integration of critical thinking within reflective thinking fosters better judgment and enhances cognitive processing. This combination empowers individuals to pause, contemplate, and devise optimal strategies for achieving objectives. The findings suggest that students proficient in reflective thinking are better equipped to hone their critical thinking skills within problem-solving contexts. This helps bridge the gap by emphasizing how reflective thinking supports

critical thinking, an area that has often been treated separately in previous research.

In cooperative classroom environments, a learning orientation can promote the practice of reflective thinking. Strategic adoption of appropriate models and approaches for reflective thinking aids in the development of advanced knowledge and competencies (Phan, 2009). However, the connection between students' learning orientations and their reflective thinking skills warrants further investigation. Our study emphasizes the need for more research into how different learning environments and strategies can better support the development of reflective thinking across diverse student groups, thus bridging the gap in understanding the role of learning orientations in reflective thinking.

Reflective thinking also profoundly impacts academic achievement, facilitating meaningful learning experiences and the development of skills such as articulation and theoretical synthesis of new knowledge (Afshar & Rahimi, 2016; Erdoğan, 2020; Fitriati et al., 2020). Reflective thinkers possess the capacity to introspect and generate novel theoretical insights, which enhances their likelihood of academic success (Hendriana et al., 2019; Kholid et al., 2020). The studies in this area suggest a strong link between reflective thinking and academic achievement, a connection that has not been fully explored in some prior studies. Our research highlights how fostering reflective thinking can provide a more structured approach to improving academic performance, which addresses this gap in literature.

Selected studies underscore the influence of reflective thinking on self-efficacy beliefs. Aspiring elementary school teachers exhibit self-efficacy beliefs that manifest their confidence in effectively imparting mathematical instruction (Yilmaz & Turan, 2020). These beliefs guide the behaviors that professional educators should display to execute successful teaching practices (Saracoglu, 2022). This empowerment enables teachers to effectively transmit mathematical knowledge and skills to students, cultivating reflective thinkers who actively inquire and question by integrating reflective thinking and inquiry methodologies into mathematical pedagogy. Our findings contribute to the literature by linking reflective thinking with teacher self-efficacy, an area that is still underexplored, especially in relation to its impact on teaching practices.

From a cognitive perspective, a substantial body of evidence substantiates the link between reflective thinking tendencies and predictive capabilities for critical thinking and problem-solving (Orakcı, 2021; Paul, 1990). Although research often delves into cognitive processes that evade conscious articulation, intricate cognitive processes within mathematical thinking are occasionally challenging to convey, particularly to younger learners (Strohmaier et al., 2020). Cognitive nuances, such as representations and biases, may elude conscious access but resonate within the learning journey (Slavin, 2019). Moreover, cognitive style exerts an influence on problem-solving efficacy (Syamsuddin et al., 2020). Our study highlights the importance of making these cognitive processes more accessible, especially in educational contexts, to bridge the gap in understanding how cognitive processes related to reflective thinking influence learning outcomes.

Cognitive nuances, such as representations and biases, may elude conscious access but resonate within the learning journey (Slavin, 2019). Moreover, cognitive style exerts an influence on problem-solving efficacy (Syamsuddin et al., 2020). Cognitive style encapsulates an individual's distinctive approach to processing and comprehending information, encompassing methods of analysis, reasoning, storage, and utilization to address problems (Mefoh et al., 2017). This cognitive disposition influences reflective thinking and problem-solving abilities

among students (Chasanah & Usodo, 2020). By identifying and addressing the impact of cognitive styles, this study helps bridge the gap in understanding how individual differences affect reflective thinking and problem-solving, which has been an underexplored area in existing research.

The quality of reflective thinking processes during mathematical problem-solving experiences diverges across individuals due to unique cognitive styles adopted by everyone. In the cognitive domain, a pivotal endeavor to nurture reflective thinking involves prompting students, prospective educators, and math teachers to tackle intricate mathematical problems, fostering introspection into problem-solving methodologies and strategies aimed at attaining objectives. Our findings indicate that developing these cognitive styles through reflective thinking can enhance mathematical problem-solving abilities and critical thinking, thus contributing to the ongoing development of reflective thinking research.

The Role of Reflective Thinking in Influencing Problem-Solving in Mathematics Classrooms

Reflective thinking in problem-solving is a dynamic process that leverages experience and knowledge to address complexity and uncover solutions to intricate issues (Farnila et al., 2021; Kholid et al., 2021; Salido et al., 2020). This process is particularly relevant in mathematics classrooms, where reflective thinking plays a crucial role in influencing problem-solving abilities. Within the spectrum of reflective thinking, categories such as productive, connective, and clarifying reflective thinking provide distinct approaches to tackling confusion in problem-solving. Reflective thinking also serves as a conduit for enhancing problem-solving competence in the classroom.

These findings help bridge the gap by demonstrating how reflective thinking enhances problem-solving skills, which has often been studied separately from cognitive and metacognitive processes. While prior research has highlighted the benefits of reflective thinking in other contexts, this study emphasizes its specific role in mathematics education, especially in the way it aids students in navigating complex problems. The findings suggest that reflective thinking not only supports individual problem-solving but also contributes to the development of higher-order cognitive skills, such as critical thinking and decision-making.

Reflective thinking functions as a catalyst for students to dissect, evaluate, and motivate themselves during the problem-solving process (Kholid et al., 2020; Ramdani et al., 2019). This fosters the development of strategies, error correction, and improved decision-making, ultimately leading to more effective problem conclusions. There is a positive correlation between reflective thinking skills and scientific attitudes, underscoring its role in influencing problem-solving (Egmir & Ocak, 2020). These findings bridge a gap in understanding how reflective thinking skills directly impact scientific attitudes and decision-making processes, an area that has been underexplored in mathematics education.

Reflective thinking is not confined to individual problem-solving; it also resonates in cooperative learning environments (Erdogan, 2019; Erdoğan, 2020). These studies assert that reflective thinking cultivates critical thinking, problem-solving, and self-regulation skills, all of which are crucial for problem-solving in a collaborative setting. By incorporating reflective thinking into group activities, educators can enhance students' ability to work together, share insights, and approach problems from multiple perspectives, further bridging the gap between individual and collective problem-solving capabilities.

By employing reflective thinking, students are empowered to grasp essential elements in comprehending a problem, establish connections between known information and mathematical operations, and correlate the problems they face with existing knowledge bases (Dubinsky, 2002; Porntaweekul et al., 2016). Specifically, reflective students exhibit a sense of caution and a high propensity to identify and rectify errors during their problem-solving journeys (Kholid et al., 2022a). Their eagerness to double-check, re-read, and recount demonstrates their dedication to ensuring the accuracy of problem-solving outcomes. This emphasis on accuracy and attention to detail is an important component in bridging the gap between conceptual understanding and practical application in mathematics.

Mathematics educators should implement tailored approaches to cater to students with diverse cognitive styles, including those inclined toward reflective thinking (Benz, 2016; Kholid et al., 2021; Prediger, 2005; Syamsuddin et al., 2020). Emphasizing the importance of meticulous work verification can help avoid erroneous answers. This aligns with the findings of this study, which suggest that reflective thinking should be integrated into teaching practices to help students refine their problem-solving strategies and improve accuracy. Moreover, reflective thinking contributes to the refinement of accuracy and concentration among students when tackling mathematical tasks (Farnila et al., 2021; Satriawan et al., 2018). It fosters an atmosphere of inquiry and enables students to justify mistakes or misconceptions, resulting in a deeper understanding of the subject matter.

Beyond mathematics education, the integration of reflective thinking carries broader implications for education in general. Encouraging students to think reflectively equips them with essential skills that transcend subject boundaries. These skills encompass critical thinking, problem-solving, decision-making, and self-regulation. The findings suggest that by nurturing reflective thinking, educators can help students build a set of transferable skills that are crucial for lifelong learning and adaptability. Therefore, educators across disciplines should consider incorporating reflective thinking into their teaching practices to prepare students for the challenges of the modern world, where adaptability and lifelong learning are paramount.

Recognizing the role of reflective thinking in problem-solving has profound implications for both mathematics education as well as education in general. Educators can equip students with the tools needed not only to excel in mathematics but also to thrive in a rapidly changing world where critical thinking and adaptability are essential (Orakcı, 2021). The findings contribute to this body of literature by offering a clearer understanding of how reflective thinking influences problem-solving in mathematics classrooms, bridging the gap between theory and practice in education.

Conclusion

The outcomes of this research furnish additional insight into the way the application of reflective thinking within the domain of mathematics learning manifests as a continuous and dynamic framework, thereby augmenting scholastic accomplishments. The acquisition of reflective thinking competencies proves indispensable in the process of devising solutions, fostering creative ideation, streamlining task completion, promoting effective learning, guiding decision-making endeavors, and refining systematic and conceptual aptitudes. The comprehensive results of the systematic review robustly suggest that pedagogical endeavors within the realm of mathematics education offer a viable avenue for nurturing the cultivation of reflective thinking. This investigation serves to reinforce the resonance of the message

emanating from existing scholarly literature, underscoring the paramount significance of fostering reflective thinking within the context of mathematics education.

Limitation and Future Research

This study has identified a considerable number of investigations pertaining to reflective thinking within the context of mathematics education. Nonetheless, it is important to acknowledge several limitations that could affect the generalizability and scope of the findings. One of the primary limitations lies in the relatively sparse availability of articles specifically addressing reflective thinking in mathematics education. This review focused on the Scopus and ERIC databases within the past five years, which may have excluded certain relevant publications due to accessibility constraints. Additionally, the scope of this study was confined to the use of specific keywords ("reflective thinking" AND "mathematics education"). As a result, the conclusions drawn from this review are circumscribed by the relatively modest pool of studies that explicitly focus on reflective thinking in mathematics education.

To uphold the robustness of this study, the selected articles underwent a comprehensive analytical process conducted by the research team, involving iterative meetings and extensive deliberations among the authors. These deliberations aimed to unearth novel insights and identify commonalities across the reviewed studies. The adherence to the PRISMA guidelines underscored the rigor of the review process. The stages of identification, screening, eligibility assessment, and eventual inclusion, integral to the data analysis, have been clearly outlined in the methods section and pertinent tables, with explicit reference to the employed approaches and methodologies.

Given these limitations, future researchers are encouraged to undertake further investigations into the implications and merits of incorporating reflective thinking within the educational sphere, particularly concerning its impact on students' cognitive growth. A key area for future research involves instilling a conviction among educators and aspiring teachers that reflective thinking significantly influences the attainment of pedagogical objectives. Subsequent research can play a crucial role in addressing existing gaps in the scholarly discourse by exploring the broader applications of reflective thinking in diverse educational settings.

Furthermore, the present analysis exclusively encompassed journal articles, and future investigations should consider the inclusion of other scholarly sources such as conference proceedings, books, and book chapters to enrich the breadth and depth of findings. While the current body of research comprises high-quality scholarly articles, expanding the scope of future inquiries to alternative publication mediums will provide a more comprehensive examination of reflective thinking and its integration into mathematics education.

Implications

This study provides a range of valuable perspectives relevant to the landscape of mathematics education within school environments. The concept of reflective thinking exerts a direct influence on the pedagogical practices within mathematics instruction. This facet presents educators with a valuable opportunity to cultivate reflective thinking competencies both within themselves and among their students. The deliberate adoption of pertinent strategies for nurturing reflective thinking by mathematics instructors holds the potential to significantly amplify the proficiencies of their students. In turn, learners are empowered to effectively apply

and grasp the knowledge they acquire within the school setting, seamlessly integrating it into practical real-world scenarios and extracurricular pursuits.

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