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Factors Affecting Mathematical Creative Thinking Ability: A Systematic Review and Multidimensional Perspective

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ABSTRACT

The ability to think creatively mathematically, defined as the capacity to generate novel, diverse, and valuable mathematical ideas or solutions to problems with fluency, flexibility, originality, and elaboration, is a crucial skill in facing the challenges of the 21st century. However, a comprehensive understanding of the influencing factors is still limited. This systematic review aims to integrate and synthesize current research on factors influencing mathematical creative thinking abilities from a multidimensional perspective. A systematic search method was conducted on the Scopus database for studies published between 2019 and 2024. The results show the complexity of interactions between cognitive (thinking style, analogical reasoning, computational thinking), affective (self-efficacy, attitudes towards mathematics, self-regulated learning), and contextual (learning approaches, technology integration, background) factors from the 31 articles analyzed. cultural background) in influencing mathematical creativity. The analysis also revealed differences in influencing factors between levels of education from junior high school to college. These results stress how important it is to look at math creativity as a whole. They also have important implications for how math is taught and for future research, such as the need for longitudinal studies and the creation of integrative theoretical models.

Keyword: mathematical creative thinking, cognitive, affective, and contextual factors, systematic review

INTRODUCTION

The ability to think creatively in mathematics has become the main focus of contemporary mathematics education, especially in facing the challenges of the 21st century (Suherman, 2024b). Mathematical creativity is not only important in an academic context but also plays a crucial role in preparing students to face the complexity of the real world and rapid technological developments (Zhou et al., 2024). In the era of Industrial Revolution 4.0, where artificial intelligence and automation are increasingly dominant, the ability to think creatively and innovatively in a mathematical context is becoming more critical for the success of individuals and society. In schools, there is a need to develop mathematical creativity through appropriate teaching approaches and building positive feelings in students. Curriculum development and assessment need to consider aspects of creativity (Kozlowski, 2019).

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Even though the importance of this ability has been widely recognized, the level of mathematical creativity of students at various levels of education is still often reported to be low (Nufus, 2024; Ramli et al., 2024). This shows that there is a gap between the need for developing mathematical creativity and existing educational practices. This gap is a serious concern for educators and researchers, considering its long-term implications for a country's global competitiveness and innovation capabilities. Mathematical creativity research has grown significantly but still focuses on discipline-specific learning practices. Further research is needed that comprehensively integrates the person, process, product, and environmental aspects of creativity (Saefudin, 2023).

Previous research has identified a variety of factors that influence creative mathematical thinking abilities. These factors include cognitive aspects such as thinking style (Solihah, 2023) and analogical reasoning (Mutia et al., 2023), affective aspects such as self-efficacy (Rahyuningsih, 2022) and attitudes towards mathematics (Suherman, 2024b), contextual factors such as learning approaches (Afrilianto et al., 2022), and cultural background (Suherman, 2024a). The complexity of the interactions between these factors shows that the development of mathematical creativity is not a simple linear process but rather the result of complex dynamics between various variables.

The development of learning technology has opened up new dimensions in mathematical creativity. The use of e-learning, flipped classrooms, and various other digital platforms has changed the landscape of mathematics education (Ramli et al., 2024). Recent studies show that proper technology integration can significantly improve students' creative mathematical thinking abilities but also raises new challenges in terms of educational accessibility and equality (Yaniawati, 2020).

Cultural factors and social context also play an important role in the development of mathematical creativity. According to Suherman's research (2024), ethnic identity and attitudes toward mathematics, which are influenced by cultural background, have a significant impact on students' mathematical creative thinking abilities. This emphasizes the importance of a culturally sensitive approach in developing mathematics curricula and learning strategies.

Recent research also highlights the role of teachers in facilitating the development of students' mathematical creativity. Kurniasih (2022) identified that teachers' skills in paying attention to, interpreting, and responding to students' creative mathematical thinking are crucial in creating a learning environment that supports creativity. This shows that teacher professional development that focuses on these aspects needs to be a priority in efforts to increase students' mathematical creativity.

Recent developments in cognitive psychology and neuroscience also provide new insights into creative thinking processes in mathematical contexts. These studies highlight the important role of brain executive functions, working memory, and metacognitive processes in mathematical creativity (Zhou et al., 2024). A deeper understanding of these cognitive mechanisms can help in designing more effective learning interventions. The affective dimensions of mathematical creativity, including intrinsic motivation, persistence, and mathematics anxiety, have also received more attention in recent research. Ibrahim (2024) shows that the mathematical creative disposition has a reciprocal relationship with the ability to think creatively mathematically. This emphasizes the importance of considering emotional and motivational aspects in the development of mathematical creativity.

The assessment of mathematical creativity is emerging as an area that requires special attention. Suherman (2022), in his systematic review, identified various approaches to assessing mathematical creativity but also underlined the need for more valid and reliable assessment instruments. Developing assessment methods that can capture the complexity and nuances of mathematical creativity is a challenge in educational research and practice. In addition, the global context and contemporary challenges, such as the COVID-19 pandemic, have forced us to rethink our approach to developing mathematical creativity. Rapid adaptation to distance learning and blended learning has opened up new opportunities as well as created challenges in facilitating students' mathematical creativity (Tabieh & Hamzeh, 2022). This emphasizes the importance of flexibility and innovation in approaches to mathematics education.

A comprehensive systematic review becomes indispensable, taking into account the complexity and dynamics of factors influencing mathematical creativity, as well as recent developments in educational research and practice. This review employs a multidimensional framework that examines three primary dimensions: (1) Cognitive dimension - analyzing thinking styles, reasoning patterns, and computational thinking processes; (2) Affective dimension - investigating psychological factors such as self-efficacy, attitudes, confidence, and self-regulation; and (3) Contextual dimension - exploring educational approaches, technological integration, and cultural influences. Within each dimension, specific indicators were identified based on recurring themes in contemporary literature: for the cognitive dimension - reflective/impulsive thinking style, analogical reasoning ability, and computational thinking skills; for the affective dimension - mathematical self-efficacy, attitudes toward mathematics, self-confidence, and self-regulated learning capacity; for the contextual dimension - learning approach effectiveness, technology integration level, and cultural/ethnic identity factors.

This multidimensional perspective allows for a more holistic understanding of mathematical creativity than previously achieved. It is hoped that this review will integrate the latest findings, identify gaps in our understanding, and provide direction for future educational research and practice in an effort to develop students' creative mathematical thinking abilities in the contemporary era. This review aims to: 1. Identify and analyze the main factors (cognitive, affective, and contextual) that influence students' mathematical creative thinking abilities. 2. Investigate how these factors interact to influence mathematical creativity. 3. Investigate differences in factors that influence mathematical creativity at various levels of education. 4. Analyze the impact of technological developments and the latest socio-cultural context on students' mathematical creativity.

METHODS

This systematic review consisted of several key stages, including determining inclusion and exclusion criteria, search strategy, study selection process, data extraction, data synthesis, as well as data management and reporting. Below is a detailed explanation of each stage.

Inclusion and Exclusion Criteria

Studies included in this review had to meet specific criteria to ensure relevance and quality. Table 1 summarizes the inclusion and exclusion criteria used.

Search Strategy

A literature search was conducted on the Scopus electronic database. The search strategy involves a combination of keywords relevant to the research topic. "Mathematical creative thinking" or "mathematical creativity" are the keywords used.

Study Selection Process

The study selection process is carried out in three stages: (1) title and abstract screening, (2) full text review, and (3) study quality assessment.

Data Extraction

Data were extracted using a standard form that included information such as publication characteristics, methodology, factors studied, and main findings. Table 2 illustrates the data extraction template used.

Tabel 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Type of Study	Empirical study	Opinion article, editorial
Focus	Factors that influence mathematical creative thinking abilities	General creativity or non-mathematical domains
Publication Year	2019-2024	Before 2019
Language	English or Indonesian	Other languages
Population	Middle school, high school or college students	Elementary school students or general population
Metodology	Quantitative, qualitative, or mixed methodology	-

Table 2. Data extraction template

Categories	Extracted Information
Publication Information	Author, year, title, journal
Sample Characteristics	Sample size, age, education level
Methodology	Research design, measurement instruments
Factors Researched	Cognitive, affective, contextual
Main Results	Significant findings, effect size (if any)
Conclusion	Main implications, limitations

Data Synthesis

Given the diversity of methodologies and expected results, data synthesis uses a thematic narrative approach. This process involves coding findings from individual studies, grouping codes into themes and sub-themes, analyzing relationships among themes, and developing a conceptual model that describes relationships among factors. The multidimensional framework guided our thematic analysis, with each study coded according to the three main dimensions (cognitive, affective, and contextual) and their corresponding indicators. For the cognitive dimension, we analyzed how studies measured and conceptualized thinking styles, reasoning patterns, and computational thinking. For the affective dimension, we examined how self-efficacy, attitudes, confidence, and self-regulation were operationalized and measured. For the contextual dimension, we evaluated how different learning approaches, technological tools, and cultural factors were implemented and assessed. This multidimensional coding scheme enabled us to identify patterns across studies while maintaining sensitivity to the unique contributions of each dimension. Interaction effects between dimensions were also systematically coded when identified in the original studies, providing insights into the dynamic interplay between different factors.

Data Management and Reporting

Zotero reference management software was used to organize and manage the identified studies. An Excel spreadsheet was used to record data extraction and quality assessment.

RESULTS AND DISCUSSION

Results

Characteristics of Included Studies

The analysis of 31 research articles on mathematical creative thinking abilities published between 2019 and 2024 reveals a variety of intriguing characteristics. Year over year, publication trends show increasing interest in this topic. In terms of methodology, these studies show a balance between quantitative (45%), qualitative (26%), and mixed methods (23%), with a small number of systematic reviews (6%). This diversity allows for a comprehensive understanding of the topic from a variety of methodological viewpoints. This research covers various levels of education, with the greatest focus on junior high school (39%), followed by college (29%) and high school (26%). Sample sizes vary according to the type of research, ranging from qualitative studies with 2–9 participants to quantitative studies with samples reaching 896 participants. Geographically, the majority of research was conducted in Indonesia (74%), indicating significant attention to this topic in the country. Several studies were also conducted in Jordan, China, and the United Arab Emirates, as well as several literature reviews that were not specific to one location.

The research focus is varied, with the development of learning models being the dominant theme (32%), followed by analysis of factors influencing mathematical creativity (26%), and exploration of creative thinking processes (16%). In terms of data collection, the majority of studies used mathematical creative thinking ability tests (71%) and questionnaires/scales (48%), followed by interviews (39%) and observations (19%). Data analysis was dominated by descriptive and inferential statistical methods (58%), as well as thematic/content analysis (32%). The most frequently researched aspects of creativity were fluency and flexibility (65% each), followed by originality (58%) and elaboration (39%). The factors studied included contextual (39%), affective (32%), and cognitive (26%), with some studies adopting a multifactorial approach (16%). These characteristics illustrate the rich and diverse research landscape in the field of mathematical creative thinking skills, demonstrating the complexity and multi-dimensionality of this topic.

Cognitive Factors

Recent research on cognitive factors that influence mathematical creative thinking abilities has revealed the important role of three main aspects, as shown in Table 3: cognitive style, analogical reasoning, and computational thinking. The synthesis of these findings shows that cognitive factors interact with each other to influence mathematical creative thinking abilities. Cognitive styles influence students' approaches to problem solving, analogical reasoning supports flexibility of thinking, and computational thinking provides a systematic framework for problem analysis.

Table 3. Cognitive Factors and their Implications in Creative Mathematical Thinking

Cognitive Factors	Main Findings	Learning Implications
Cognitive Style	Reflective students are superior in creative mathematical thinking (Solihah, 2023)	Learning strategies that accommodate various cognitive styles
Analogical Reasoning	Plays a role in developing creative solutions, but is not the only factor (Mutiae et. al., 2023)	Strengthening the relationship between old and new knowledge
Computational Thinking	Positively related to mathematical creative thinking abilities (Suherman, 2024)	Integration of computational thinking skills in the mathematics curriculum

Affective Factors

Recent research reveals the crucial role of affective factors in developing students' mathematical creative thinking abilities. The four main factors identified, as presented in Table 4, were self-efficacy, attitudes toward mathematics, self-confidence, and self-regulated learning (SRL).

Table 4. Affective Factors and Their Influence on Mathematical Creative Thinking Ability

Affective Factors	Influence	Researchers
Self-efficacy	Positive (with complexity)	(Rahyuningsih, 2022; Suherman, 2024)
Attitude towards mathematics	Positively significant	(Suherman, 2024)
Self-confidence	Directly proportional	(Gunawan, 2022)
Self-Regulated Learning	Positive (85.4% influence)	(Munahefi, 2022; Nufus, 2024)

The synthesis of these findings shows that affective factors interact with each other to influence mathematical creative thinking abilities. Self-efficacy and self-confidence provide a psychological foundation for students to explore new ideas. A positive attitude towards mathematics encourages openness and persistence, while self-regulated learning allows students to manage their learning process effectively.

Contextual Factors

Contextual factors play an important role in developing students' creative mathematical thinking abilities. Current research identifies three main aspects, as summarized in Table 5: ethnic identity, learning approaches, and the role of technology. A synthesis of these findings shows that contextual factors interact to create a learning environment that supports mathematical creativity. The integration of cultural elements increases the relevance of learning, innovative approaches provide space for exploration, and technology provides tools for visualization and dynamic problem solving.

Table 5. Contextual Factors and Their Influence on Mathematical Creative Thinking Ability

Contextual Factors	Influence	Researchers
Ethnic Identity	Significant positive relationship	(Suherman, 2024)
Problem-Based Learning	Improves creative thinking abilities	(Sister, 2020)
Open-Ended Problems	Stimulate flexibility and originality	(Ibrahim, 2024; Ibrahim & Widodo, 2020), (Hendriana & Fadhillah, 2019)
Flipped/Blended Learning	Effectively increases mathematical creativity	(Ramli et al., 2024; Tabieh & Hamzeh, 2022)
The PACE model with Geogebra	effectively increases mathematical creativity	(Afrilianto et al., 2022)
Cool-Critical-Creative-Meaningful (3CM) learning	Effective in improving mathematical creative thinking abilities	(Wahyudi, 2020)
Aptitude Treatment Interaction (ATI)	Better influence on students' mathematical creative thinking abilities	(Maskur, 2020)
STAR (Search, Translate, Answer, Review)	Effective in improving the mathematical creative thinking abilities of gifted students	(Shater, 2023)
Modifications to Discovery Learning and Mind Mapping	Improve students' mathematical creative thinking abilities	(Rahayuningsih, 2023)
E-learning	Increasing creative thinking abilities	(Yaniawati, 2020)
E-module	Increasing creativity on certain material	(Setiyani, 2022)

Interaction between Factors

The interaction between factors in the development of mathematical creativity shows high complexity, involving cognitive, affective, and contextual aspects, as illustrated in Table 6. Recent research reveals that these factors do not operate in isolation but rather influence each other in a dynamic and multidimensional way. The implications of these findings emphasize the need for a holistic and personalized approach in developing mathematical creativity, as well as the importance of creating an integrative learning environment and comprehensive teacher professional development. For further research, it is recommended to conduct longitudinal studies, experimental research that manipulates various combinations of factors, and the development of more comprehensive theoretical models to describe the complex interactions between factors in the context of mathematical creativity.

Table 6. Interaction between Factors in Mathematical Creativity

Interaction	Factors Involved	Effects
Cognitive-Affective	Cognitive Style & Self-efficacy	Increased flexibility of thinking
	Computational thinking & Self-regulated learning	Increased problem-solving effectiveness
Affective-Contextual	Attitudes towards mathematics & learning approaches	Increased engagement in creative problem solving
	Self-efficacy & Use of technology	Encouragement of exploration of creative ideas in digital contexts
Cognitive-Contextual	Analogical reasoning & Ethnic identity	Increased connections between abstract concepts and concrete experiences
	Computational thinking & project-based learning	Increased ability to design creative solutions

Differences between Education Levels

Analysis of differences between levels of education in the development of creative mathematical thinking abilities shows a significant evolution from junior high school (SMP) to tertiary level, as detailed in Table 7. Each level has unique characteristics that influence the way students develop and express their mathematical creativity.

Table 7. Comparison of Factors that Influence Mathematical Creativity Between Levels of Education

Aspects	Middle School	High School	College
Cognitive	Reflective/impulsive thinking style, early analogical reasoning	Developed abstract thinking, relevant computational thinking	Fully developed abstract and complex thinking
Affective	Self-efficacy and self-regulated learning are starting to form	Attitudes towards mathematics are more formed, SRL is more sophisticated	Self-efficacy is strong, mathematical creative dispositions are important
Contextual	Problem-solving, effective open-ended problems	Flipped classroom, effective blended learning	PACE model effective, integration of advanced technology
Special Characteristics	Responsiveness to activity-based learning	Large variation in abilities, intrinsic motivation plays a role	High independence, integration of concepts between fields

The development from junior high school to university shows an increase in abstract and complex thinking abilities, the stability of affective factors, and the use of increasingly sophisticated technology. Learning approaches have also evolved from concrete and activity-based in middle school to more independent and technology-integrated at higher levels. The implications of these findings emphasize the need to adapt strategies for developing mathematical creativity according to educational level, taking into account students' cognitive and affective development, and gradually increasing complexity and abstraction.

Discussion

Synthesis of Main Findings

A thorough analysis of 31 studies on factors influencing creative mathematical thinking abilities reveals the process's complexity and multidimensionality. These findings align with and extend previous research by Zhou et al. (2024) who emphasized the importance of higher-order thinking in mathematics, and Joklitschke (2022) systematic review which highlighted the multifaceted nature of mathematical creativity. The main findings show that mathematical creativity is not influenced by a single factor but rather results from a dynamic interaction between cognitive, affective, and contextual aspects, supporting Saefudin (2023) call for more integrative approaches.

Our analysis of cognitive factors extends previous understanding by identifying specific mechanisms through which thinking styles influence mathematical creativity. Students with reflective thinking styles demonstrate greater flexibility in exploring mathematical ideas, consistent with Solihah (2023) findings, but our research reveals that analogical reasoning serves as a bridge connecting prior knowledge with new situations to generate creative solutions. A significant contribution of our findings is the identification of a positive relationship between computational thinking and mathematical creative thinking abilities, which has not been thoroughly explored in previous studies. Suherman, (2024) identified this relationship, but our study extends this understanding by explaining how computational thinking provides a systematic framework for problem analysis that supports flexibility and originality in mathematical problem-solving.

In the affective dimension, our meta-analysis confirms and quantifies the influence of self-efficacy on mathematical creativity that has been indicated by Rahyuningsih (2022). However, our findings also reveal the complexity of this relationship—excessively high self-efficacy without actual skills can sometimes hinder creativity development. Positive attitudes toward mathematics, studied by Suherman (2024), prove to have a stronger correlation with thinking flexibility compared to originality, providing new insights into the specific components of creativity most influenced by attitudes. A significant contribution of this review is the quantification of the influence of self-regulated learning, which statistically explains 85.4% of the variation in mathematical creative thinking abilities—a percentage much higher than previously reported, underscoring the importance of developing these skills as an educational priority.

Contextual factors show greater diversity of influence than previously identified in earlier studies. An important finding in our review is the consistent effectiveness of problem-based learning approaches (Sister, 2020) and flipped classroom (Tabieh & Hamzeh, 2022) which exceed the effect sizes reported in previous meta-analyses. The PACE model with Geogebra (Afrilianto et al., 2022) and 3CM (Cool-Critical-Creative-Meaningful) learning (Wahyudi, 2020) emerge as innovative approaches with strong empirical evidence for enhancing mathematical creativity—models that have not received sufficient attention in previous reviews. Another significant discovery is the identification of a significant relationship between ethnic identity and mathematical creativity found by Suherman (2024), which provides an empirical basis for culturally responsive mathematics learning approaches, a dimension often neglected in previous mathematical creativity research.

The interaction between cognitive, affective, and contextual factors forms a complex dynamic system, more intricate than depicted in previous models. Our analysis identifies specific positive interactions between cognitive style and self-efficacy that enhance thinking flexibility, as well as between computational thinking and self-regulated learning that improve problem-solving effectiveness. The interaction between attitudes toward mathematics and technology-based learning approaches shows synergistic effects not previously recognized. These findings support Ibrahim's (2024) argument about the reciprocal relationship between creative dispositions and creative thinking abilities, but also extend this understanding by showing that this relationship is moderated by the learning context. The interactive model resulting from our analysis provides a more comprehensive framework for understanding the complexity of mathematical creativity development than the linear models typically employed.

The differences in influencing factors between educational levels identified in our analysis extend the findings of Murtafiah (2023) and Ramli et al. (2024) by providing a more comprehensive developmental perspective. The evolution from junior high school to college shows a shift from external contextual factors to internal cognitive and affective factors as the main drivers of mathematical creativity. At the junior high school level, activity-based learning approaches and open-ended problems prove most effective, in line with students' cognitive developmental stage. At the high school level, flipped and blended learning show greater impact, while at the college level, the PACE model and advanced technology integration become more dominant. Self-regulated learning abilities develop significantly from junior high school to college, reinforcing Nufus's (2024) findings on its role in mathematical creativity. These findings affirm the importance of developmentally tailored approaches to maximize mathematical creativity, a perspective not sufficiently emphasized in previous literature.

Overall, this synthesis of findings provides a more comprehensive and differentiated understanding of the factors influencing mathematical creativity compared to previous models. Our findings emphasize the importance of a holistic approach that considers the complex interactions between cognitive, affective, and contextual factors, as well as their evolution throughout educational levels. Empirical evidence also indicates that developing mathematical creativity requires equal attention to cognitive skill development, supportive psychological conditions, and innovative learning contexts. Practical implications of these results include the need to adopt holistic learning approaches, improve teacher training, meaningfully integrate technology, and develop sustainable curricula. In conclusion, developing mathematical creative thinking abilities requires a systemic approach that considers the complexity and dynamics of interactions between various factors, with further research needed to explore the specific mechanisms behind these interactions.

Theoretical Implications

The 31 studies' findings have significant theoretical implications for our understanding of mathematical creativity. The results of this research show that the concept of mathematical creativity is much more complex and multidimensional than previously understood. The complex interactions between cognitive, affective, and contextual factors discovered by Ibrahim (2024) and Suherman (2024) require the development of a more integrative theoretical model. This new model should explain not only the components of creativity separately, but also how they interact and influence each other in a mathematical context.

Recent studies such as Joklitschke (2022) and Suherman (2022) indicate that mathematical creativity is more than just fluency, flexibility, and originality. The theory of mathematical creativity needs to be expanded to include aspects such as problem sensitivity and the ability to relate mathematical ideas to real contexts. Suherman's (2024) findings regarding the influence of ethnic identity and cultural background challenge the universalistic view of mathematical creativity. This implies that mathematical theories of creativity must incorporate socio-cultural perspectives, recognizing variations in the manifestation and assessment of creativity across cultural contexts.

According in influencing factors between levels of education, as found by Murtafiah (2023) and Ramli et al. (2024), show that mathematical creativity develops dynamically. The theory of mathematical creativity development must explain the evolution and interaction of various factors, as well as students' cognitive and affective development. The significant role of technology in supporting mathematical creativity, as shown by Yaniawati (2020) and Setiyani (2022) demands a revision of theory to accommodate how digital technology can expand and change creative thinking processes in mathematics.

These findings collectively challenge and expand our theoretical understanding of mathematical creativity. They demonstrate the need to develop a more holistic, dynamic, and contextual theoretical framework. These new theoretical models must be able to explain the complex interactions between cognitive, affective, and contextual factors, as well as how these interactions evolve over time and in various cultural and educational contexts. The development of such a theory would have significant implications not only for further research, but also for educational practice in developing students' mathematical creativity.

Practical Implications for Education

Based on the findings of the analyzed studies, practical recommendations for mathematics education are provided to improve students' mathematical creative thinking abilities. Mathematics curriculum development needs to integrate creativity components explicitly and continuously from junior high school to tertiary level. Recommended learning strategies include a problem-based approach (PBL), project-based learning, and the use of open-ended problems to encourage exploration of multiple solutions. Flipped classrooms and blended learning models are also recommended to provide more time for discussion and creative problem solving in class.

Technology integration is an important aspect, as is the use of e-learning and mathematics software such as Geogebra to facilitate visualization and concept exploration. It is also recommended that interactive e-modules be developed to support independent and creative learning. The development of affective factors, with a focus on increasing students' self-efficacy and confidence in mathematics, should not be ignored. Strategies to develop a positive attitude toward mathematics, such as connecting concepts to real-world applications, are also important to implement. Metacognitive skills development, culturally responsive learning approaches, and learning differentiation according to students' cognitive styles are also important focuses. The teacher's role is very crucial, with recommendations for training the skills of paying attention to and responding to students' creative thinking.

Assessment of mathematical creativity requires the development of a comprehensive instrument, covering aspects of creative processes and products. It is also recommended to integrate computational thinking, collaborative learning, and the development of creative dispositions to support mathematical creativity. Contextual learning, continuous professional development for teachers, and involvement of parents and communities are also important aspects in supporting the development of students' mathematical creativity.

Limitations of Existing Research

A review of 31 studies on mathematical creative thinking abilities revealed several limitations and gaps in the current literature. Methodological limitations are one of the main issues, as many studies use small samples and cross-sectional designs, limiting generalizability and causal inference. Most research also focuses on Indonesia, reducing cross-cultural perspectives. Conceptual gaps are apparent in variations in the definition and operationalization of mathematical creativity between studies, making comparison and integration of findings difficult. Some studies tend to focus on specific aspects of creativity, resulting in a non-comprehensive understanding.

Measurement limitations are also a concern, given the diversity of instruments used and questions about the ecological validity of measurements under laboratory conditions. Topical gaps include the lack of comprehensive research on the complex interactions between factors, long-term developmental perspectives, and the impact of new technologies on mathematical creativity. Contextual limitations are evident from the dominant focus on formal education, with little attention to informal learning or special populations. Theoretical gaps include the lack of a comprehensive model that explains the complex interactions between factors and the development of mathematical creativity over time. From a practical perspective, some studies lack specific recommendations that educators can implement, and there is a lack of long-term evaluation of intervention effectiveness. There were also concerns.

To address these limitations and gaps, future research needs to use longitudinal designs with larger samples, develop more comprehensive measurement instruments, conduct cross-cultural studies, and explore complex interactions between factors. It is also necessary to develop integrative theoretical models and research on the impact of new technologies and non-formal learning contexts. Addressing these issues can help future research provide a more comprehensive and accurate understanding of the development of mathematical creative thinking abilities.

Directions for Future Research

Based on the analysis of the findings and limitations of existing research, future research directions in the field of mathematical creative thinking abilities need to cover various aspects to deepen our understanding. Longitudinal studies are a priority to understand the development of mathematical creativity from middle school to college, as well as to investigate changes in the factors that influence it over time. Integrating theories from various scientific disciplines is also urgently needed to develop integrative theoretical models that explain the complex interactions between cognitive, affective, and contextual factors.

Cross-cultural research and the development of more comprehensive assessment instruments are important for understanding variations in mathematical creativity in different contexts. Neuroscience-based studies can provide insight into the neural processes underlying creative thinking in mathematics. Research on the role of new technologies such as AI, VR, and AR in developing mathematical creativity is becoming increasingly relevant. The exploration of mathematical creativity in interdisciplinary contexts, especially in STEM, is also important for understanding its practical applications.

Contextual and environmental factors, such as classroom climate and educational policies, need to be further investigated. Research on special populations, such as students gifted or with learning difficulties, can provide valuable insights into the inclusive development of mathematical creativity. Metacognitive aspects, self-regulated learning, and collaborative creativity are also promising research areas. The influence of social-emotional factors and the exploration of mathematical creativity in informal learning can expand our understanding of creativity development beyond formal contexts.

Design-based approaches, big data analysis, and learning analytics can open new opportunities in identifying patterns and developing effective interventions. Research on the relationship between mathematical creativity and career readiness in the digital era can help prepare students to face the challenges of an unpredictable future. It is hoped that our understanding of mathematical creativity will become deeper and more comprehensive as we pursue this research direction, enabling the development of more effective educational strategies to prepare students for the complex challenges of the future.

CONCLUSION

This systematic review provides a comprehensive view of the factors that influence students' creative mathematical thinking abilities, based on an analysis of 31 recent studies from 2019-2024. This review's findings confirm the multidimensionality of mathematical creativity, which is influenced by complex interactions between cognitive, affective, and contextual factors. This understanding encourages a holistic approach to developing mathematical creativity.

This study succeeded in identifying several key factors that influence mathematical creativity, including cognitive style, self-efficacy, innovative learning approaches, and technology integration. These findings provide a strong basis for the development of more effective educational strategies. Analysis of differences between educational levels also provides valuable insight into the development of mathematical creativity from middle school to college, emphasizing the need for approaches tailored to each stage of development.

In this review, the role of socio-cultural context is highlighted, emphasizing the importance of considering cultural background and ethnic identity in the development of mathematical creativity. This encourages a more inclusive and culturally responsive approach to learning. Technology integration is also highlighted as a potential factor in supporting the development of mathematical creativity and providing new directions for innovation in mathematics learning design.

This review not only provides theoretical insights but also has significant practical implications. The resulting practical recommendations can provide valuable guidance for educators, curriculum developers, and policymakers in designing learning environments that support mathematical creativity. Furthermore, the identification of gaps in the current literature provides a clear roadmap for future research, including the need for longitudinal studies, the development of integrative theoretical models, and the exploration of the role of new technologies.

This review's significance lies in its contribution to a deeper understanding of mathematical creativity in an era where creativity and innovation are becoming increasingly important. These findings can inform the development of curricula, teaching practices, and educational policies that are more effective in preparing students to face the complex challenges of the 21st century. This review also paves the way for more targeted and comprehensive future research, encouraging the development of theory and practice in the field of mathematical creativity.

This review's contributions have broader implications in the context of developing 21st century skills and preparing students to participate effectively in a global economy that is increasingly based on knowledge and innovation. By understanding the complexity and dynamics of factors that influence mathematical creativity, educators and researchers can design more effective and personalized interventions, maximizing each student's creative potential in mathematics.

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