*International Journal of Instruction* *October 2025 ● Vol.18, No.4*
*e-ISSN: 1308-1470 ● www.e-iji.net* *p-ISSN: 1694-609X*
*pp. 39-56*

Article submission code: 20250119171649
Received: 19/01/2025
Revision: 05/04/2025
Accepted: 13/04/2025
OnlineFirst: 01/07/2025

# Enhancing Undergraduates' Creative Thinking through Mathematics Courses: A Systematic Literature Review

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Creative thinking (CT) is recognized as a critical competency for global citizens in the 21st century. Despite its significance, systematic reviews examining instructional interventions designed to foster CT in undergraduate mathematics courses remain scare. This study, following PRISMA guidelines, conducts a systematic literature review of articles published between 2019 and 2024. Relevant studies were identified by searching databases such as Web of Science, Scopus, focusing on interventions aimed at enhancing CT in undergraduates within mathematics courses. A selection process narrowed down 589 initially identified articles to 17 relevant studies for in-depth analysis. Both quantitative and qualitative research methodologies were employed to evaluate the characteristics, effectiveness, and assessment tools associated with these interventions. This study emphasizes the importance of strategic pedagogical practices and rigorous evaluation methods in fostering CT within the context of university-level mathematics education. The findings highlight the need for educators to clearly define the objectives of CT, including its attributes, criteria, and standards, prior to implementing any other disciplines to promote CT, various teaching strategies were identified, offering diverse approaches for cultivating CT among undergraduates. However, the effectiveness of these strategies is highly contingent upon their flexibility and accessibility, which allow both students and instructors to adapt and align their efforts effectively. Furthermore, the use of varied assessment tools is critical to accurately measuring the impact of these instructional interventions.

Keywords: creative thinking, mathematics education, higher education, instructional intervention, PBL

## INTRODUCTION

Education in the 21st century faces increasingly complexity and challenges as societal, and workforce demands continue evolve. There is a growing emphasis on equipping students with essential competencies such as problem-solving, critical thinking, and creative thinking (Dilekçi & Karatay, 2023). The United Nations Educational,

**Citation:** Zhao, S., & Abdullah, A. H. (2025). Enhancing undergraduates' creative thinking through mathematics courses: A systematic literature review. *International Journal of Instruction*, *18*(4), 39-56.

Scientific, and Cultural Organization identifies several key challenges for future education, including ensuring equitable and sustainable systems (Carney, 2021). According to Rios et al. (2020), the Partnership for 21st century Skills highlights the importance of integrating mathematics and creativity into higher education curricula, with mathematics being identified as a fundamental skill and creativity as a critical applied competency (Mubarak & Selimin, 2023).

As educators recognize the importance of preparing students for real-world challenges, creativity has emerged as a crucial factor for success. Traditional mathematics instruction often lacks emphasis on CT. This has led to a shift in the educational paradigm, emphasizing the role of CT in addressing problems innovatively and fostering deeper engagement with knowledge (Riniati, 2022). The demand for diversified, creativity-focused teaching approaches is growing, as they not only promote a more profound understanding of mathematical concepts but also prepare students to adapt to the ever-changing world (Samaniego et al., 2024). Technological advancements, in particular, have transformed how information is accessed and problems are solved, making it essential for students to develop CT skills to use technology innovatively and effectively (Falco, 2017). This underscores the urgent need for an educational approach that prioritizes CT as a cornerstone of effective need for an educational approach that places CT at the core of learning and problem-solving, particularly in mathematics education (Suganda et al., 2021).

**Creative Thinking**

CT is considered a core component of the 21st-century skills framework, alongside critical thinking, communication, and collaboration (Abdulla & Runco, 2018). Scholars have approached CT from various perspectives, offering nuanced definitions that emphasize its multifaceted nature. (Mohrman & Winby, 2018). Hernández Jaime et al. (2018) characterize CT as the ability to innovate and act uniquely, offering new insights and solutions. Al-Mahasneh (2018) defines CT as a high-level intellectual process that modifies conventional ideas to generate alternative solutions. Similarly, Khuana et al. (2017) highlight CT as an intellectual process fostering new strategies and viewpoints for addressing complex problems. These definitions reflect CT' potential for generating innovative solutions to real-world challenges (Leksmono et al., 2019). As Samaniego et al. (2024)suggest, creative activities are essential for students to master the skills necessary for success in the 21st century.

Singapore's national curriculum explicitly emphasizes "inventive thinking" as a core educational goal, while British Columbia, Canada, identifies CT as one of the three fundamental competencies. Similarly, Israeli's national mathematics syllabus highlights problem-solving activities that encourage "thinking and creativity". The ability to synthesize knowledge, experience, and insights to generate novel ideas and solutions is crucial for student success both academically and professionally (OECD, 2019). Despite its importance, educators often face challenges in effectively fostering and assessing CT (Schmidt, 2012). While research underscores the necessity of CT to prepare students for an uncertain future, there is a lack of practical frameworks for teaching and evaluating this skill (Abdulla & Cramond, 2017). Integrated learning models, such as Problem-

Based Learning (PBL) and STEM (Science, Technology, Engineering, and Mathematics), provide robust platforms for cultivating CT. By immersing learners in contexts that require real-world problem solving, educators can foster deeper cognitive engagement and an academic culture that prioritizes creativity and innovation (Jawad et al., 2021).

### Creative Thinking in Mathematics Education

Creative thinking (CT) is an essential skill for developing innovative solutions to mathematical problems and applying mathematical concepts to real-world challenges. Additionally, the nature of mathematics offers an ideal platform for cultivating creativity (Maisyarah & Mulyono, 2020).The significance of fostering CT in mathematics has been recognized globally (Catarino et al., 2019). However, the implementation of CT in mathematics education presents challenges, as there is no universally accepted framework for defining and accessing CT in this context.

Several scholars have proposed diverse interpretations of CT in mathematics. Ervynck (1991) defines CT as the ability to formulate mathematical objectives and identify their intrinsic relationships. Runco (1993) emphasizes the role of both divergent and convergent thinking, problem identification and the discovery of new relationships. Haylock (1987) points to the importance of discovering novel connections between methods and applications, while Silver (1997) characterizes CT with mental flexibility, curiosity, and the ability to generate new ideas and solutions. Other scholars, such Demetriou et al. (2022) highlight the importance of hypothesis formation, argumentation, and proof construction as key elements of CT in mathematics (Leikin, 2009). The varied definitions of CT in mathematics can be categorized into three dimensions: divergent thinking (generating multiple solutions and exploring alternative approaches), integrative thinking (synthesizing ideas to identify mathematical patterns), and lateral thinking (innovative methods to approach problems) (Miman et al., 2016).

### Goals of this Systematic Review

Despite the growing importance of CT in mathematics education, a systematic review of instructional interventions aimed at enhancing CT in undergraduate mathematic courses is lacking. This review aims to fill this gap by analysing key characteristics of such interventions, including study design, teaching methods, assessment tools, and outcomes. The review focuses on studies published between 2019 and 2024, offering insights into the effectiveness of various strategies for fostering CT. The goal is to provide practical recommendations for instructors to implement effective instructional strategies and appropriate assessment methods to enhance students' CT in mathematics courses. Additionally, this review will contribute to the broader research agenda on the development of CT and serve as a reference for further studies in this field.

## METHOD

### Systematic Review Design and Search Process

This systematic literature review follows the PRISMA 2020 flow guideline, with its checklist items widely applied to systematic reviews evaluating interventions

(Abdullah, 2022). The literature search was conducted from January 1,2019 to July 31, 2024, using the Scopus and Web of Science (WoS) databases. A total of 272 articles from WoS and 317 articles from Scopus. Only empirical studies published in English were included. The following three sets of keywords combined using the operators "AND" and "OR": creative thinking; mathematics education OR mathematics teaching OR mathematics learning; and university OR college OR higher education OR postsecondary education OR tertiary education.

**Screening and Eligibility Studies**

The authors screened the titles and abstracts using the following inclusion criteria:(1) the study must focus on the development or improvement of CT; (2) the study must involve an instructional intervention; (3) the study must report on participants' CT outcomes resulting from the treatment; (4) the study must involve students in higher education; (5) the instructional intervention must be within the field of mathematics in higher education; and (6) the articles must be publicly available or archived, and must be empirical research or program evaluations. Notably, all inclusion criteria had to be met; studies that did not satisfy any one of these criteria were excluded. For instance: (1) some articles evaluated and improved the CT of pre-service math teachers through mathematics education courses focused on elementary mathematics but not related to the mathematics of higher education, (2) several studies worked on improving the CT strategies for secondary; however, not postsecondary students, and (3) many articles mentioned that CT is necessary for students to obtain mathematics achievement; nevertheless, they did not develop CT intervention strategies or relevant training.

To ensure the credibility of the reviewed studies, the authors established explicit exclusion criteria. Conference proceedings and books were excluded, as these sources do not undergo a rigorous peer-review process, which is essential for maintaining academic reliability and methodological transparency. Furthermore, non-English publications, editorials, review articles, and studies lacking empirical data were also excluded to ensure consistency in research methodology and comparability across studies. Further screening was conducted by reading the full texts of 81 studies that met the original inclusion criteria. The two authors discussed these uncertain, included, or excluded studies until they reached an agreement. Finally, 17 articles remained for data extraction and analysis. The flow diagram is shown in Figure 1.

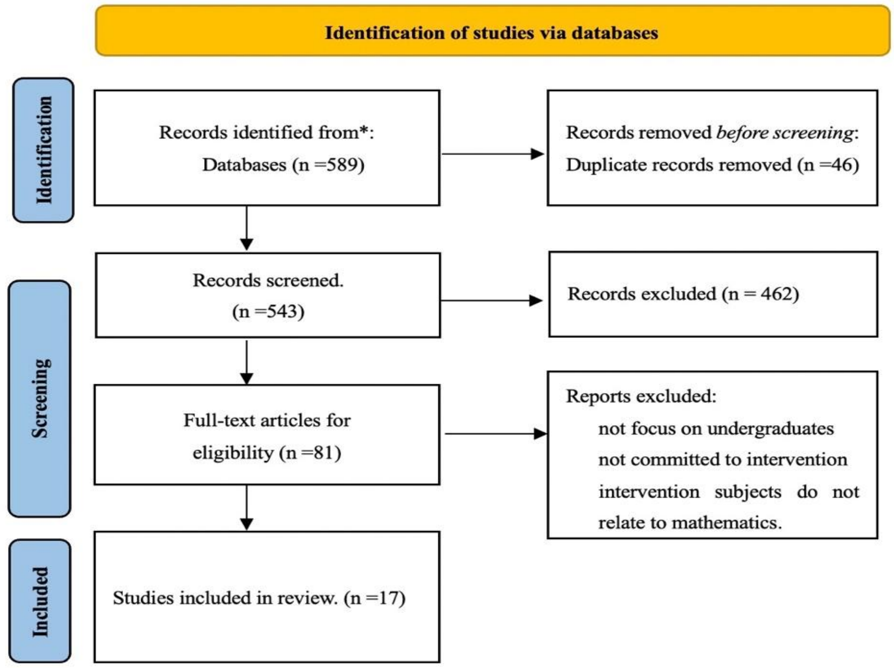


Figure 1
PRISMA flow diagram

**Data Analysis**

The 17 studies were thoroughly analysed. A codebook was created, listing the key coding categories of interest, as indicated in Table 1, to guide the data extraction process. Following this, the mixed research synthesis method proposed by Adrion and Bowers (Bravo et al., 2015). To combine the data, a “counting” strategy was used, where categories related to countries, student grade levels, and research methods were computed and tagged. A general summary of the research patterns was provided through descriptive statistical analysis. Additionally, the constant comparative method was employed for thematic analysis to examine data related to intervention characteristics and outcomes (Wang & Abdullah, 2024). Throughout the entire analysis process, peer checking was also conducted to ensure the reliability of the findings.

Table 1
The number of students attending culture courses

| Coding category | Sub-category | Code examples |
|---|---|---|
| Study Characteristics | Publication Outlet | •International Journal of Interactive Mobile Technologies , International Journal of Advanced Science and Technology , International Journal of Emerging Technologies in Learning , International Journal of Evaluation And Research in Education, International Journal of Mathematical Education in Science and Technology, International Journal of Scientific and Technology Research, Journal for the Education of Gifted Young Scientists, Journal of Higher Education Theory and Practice, Journal of Institutional Research South East Asia, Journal on Mathematics Education, Perspektivy Nauki I Obrazovania, Reice Revista Iberoamericana Sobre Calidad Eficacia Y Cambio en Educacion, Universal Journal of Educational Research, World Transactions on Engineering and Technology Education, Uniciencia . |
| | Publication Year | • 2019, 2020 2021, 2022, 2023, 2024 |
| | Country | • Indonesia, Iraq, Portugal, Jordan, Malaysia, Turkey, Ukraine, China. |
| Intervention Characteristics | Research Design | • Quasi-experiment, experiment, Descriptive Study, Research and Development(R&D), Observational Study, Case Study, CAR. |
| | Length of Intervention | • One month, One semester, Two semesters |
| | Number of Participants | • 24–250 (students from mathematics related courses) |
| | Mathematics Topics | • Statistics and Probability, Mathematical Literacy, Elementary Mathematics, Km Systems and Engineering, Linear Algebra, Mathematics Education, Calculus. |
| | College of Participants | • Education, Child Development, Mathematics. |
| | Features of Intervention | •MCTBML, PANGTUS, PBL, Cooperative learning, VBA, Alan Hoffer's model, Scratch Programming Project, Mind map, Discovery learning, STEM education, assessment, Flipped classroom model. |
| Outcomes | CT Outcomes | • Creative Thinking (CT) improvement |
| | Academic Outcomes | • Mathematical Literacy, Divergent Thinking Ability, Academic Achievement, Engagement in Mathematics learning, Computing Power |

The main coding categories, subcategories, and examples of article coding, as presented in Table 1, formed the framework for organizing and presenting the results in this section. The discussion begins with the findings related to study and intervention characteristics, followed by an analysis of program practices and reported outcomes.

**FINDINGS**

**Study Characteristics**

Figure 2 presents the main descriptive characteristics of the 17 studies reviewed. The studies were conducted in Indonesia, Portugal, Jordan, Iraq, China, Turkey, Ukraine, USA, Malaysia. Early studies from 2019 to 2020 primarily explored models for CT integration in mathematics, focusing on cooperative learning, problem-based learning (PBL), and STEM approaches. From 2021 to 2022, the focus shifted towards digital learning interventions, incorporating computational programming, flipped classroom, and dynamic mathematical software. Recently, from 2023 to 2024, studies have increasingly emphasized interdisciplinary strategies and data-driven assessment methods, highlighting CT assessment tools, AI-driven learning analytics, and cross-disciplinary applications in STEM and real-world problem-solving. In terms of research methods, qualitative, quantitative, and mixed research methods were used in five (29%), seven (42%), and five (29%) studies. Qualitative data were collected using interviews, observations, and questionnaires while quantitative data were gathered through tests. Regarding research design, six of the 17 studies examined (35%) used a quasi-experimental methodology, four studies (23.5%) used a descriptive methodology, and three studies (18%) used an experimental methodology. Additionally, four studies (23.5%) employed other methodologies. Appendix A contains the titles, authors, and sources of the 17 studies reviewed.

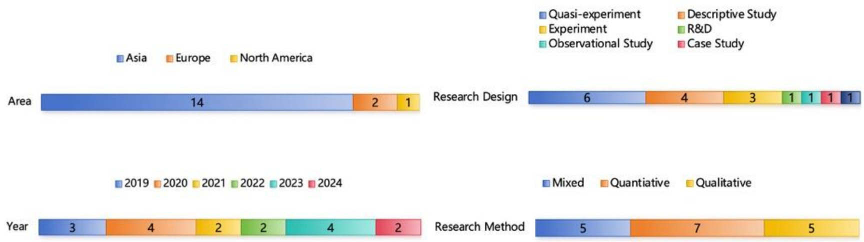


Figure 2
Study characteristics of the reviewed studies (Number of studies n=17)

**Intervention Characteristic**

The reviewed studies examined interventions targeting undergraduate students, with sample sizes ranging from 24 to 250 students. Among these, three studies (18%) focused on child development, while five studies (29%) specially targeted mathematics education students. In nine studies (53%), the students' majors were not specified. The mathematics topics covered in the studies included statistics and probability, mathematical literacy, elementary mathematics, systems and engineering, linear algebra, mathematics education, and calculus. These findings highlight the broad applicability of CT interventions across various mathematical domains, reinforcing the need for tailored instructional strategies that align with specific content areas.

To clarify intervention characteristics, this study categorized them based on their impact on mathematics education. The reviewed interventions included collaborative learning models, technology-enhanced instructional approaches, and structured instructional frameworks. For example, Cooperative learning models, used in 12% of studies, were commonly used in probability and statistics, promoting collaborative problem-solving. Meanwhile, technology-enhanced instructional approaches played a pivotal role in CT development. Scratch programming, flipped learning, and dynamic mathematical software were among the most frequently used tools, demonstrating their effectiveness in fostering computational creativity, self-directed learning, and interactive engagement.

Other digital learning tools, such as Visual Basic for Applications (VBA), online learning platforms, and virtual simulations. Structured instructional frameworks encompassed a variety of teaching methodologies designed to systematically enhance CT. These include problem-based learning (PBL) applied in 24% of studies, particularly in calculus and linear algebra, fostering inquiry-driven learning and analytical reasoning. Alan Hoffer's model of teaching and learning, project-based learning (PBL), mind mapping exploratory learning, online the ADDIE model, discovery learning, the STEM approach, creative teaching, and alternative assessment. This categorization provides a comprehensive framework for understanding how different instructional strategies influence CT development in undergraduate mathematics education, ensuring greater clarity in linking intervention types to their respective course applications.

**Interdisciplinary Analysis**

In contemporary mathematics education research, interdisciplinary integration has emerged as a crucial strategy for fostering teaching innovation and improving learning outcomes (Asmara et al., 2024). The integration of mathematics education with other disciplines, such as educational technology, computer science, psychology, and STEM, offers a fresh perspective for enhancing students' CT (Carlisle & Weaver, 2018). Studies have shown that educational technology plays a key role in nurturing their CT (Ariani et al., 2022). Innovative teaching approaches, such as flipped classrooms and PBL, effectively enhance both students' mathematical achievement and their CT (Daha, 2025).

Six studies (35%) focus on the integration of mathematics education with educational technology, emphasizing the innovative application of technology in mathematics instruction. Five studies (29%) focus on the integration of computer science and mathematics education, emphasizing the role of technical tools, such as programming and dynamic mathematical software, in mathematics education, especially in fostering computational thinking and creative problem-solving skills. Scratch and dynamic mathematics software not only deepen students' understanding of mathematical concepts but also significantly enhance their CT in mathematical problem-solving (Mohd Tahir et al., 2023; Somsak et al., 2023).

Four studies (24%) focus solely on mathematics education, concentrating on teaching methods and strategies that effectively promote the development of students' CT. These studies emphasize that the core of mathematics education lies in designing and implementing effective teaching strategies that stimulate students' curiosity and creativity, particularly in relation to their cognitive abilities and learning motivations.

Two studies (12%) incorporate STEM education, emphasizing the integration of mathematics with science, technology, and engineering, and driving the development of interdisciplinary learning models. The implementation of STEM education has been shown to not only enhance students' mathematical abilities but also promote their overall problem-solving capabilities and CT across other disciplines (Jawad et al., 2021).

It is evident that the combination of educational technology and mathematics education constitutes the largest proportion (35%), followed closely by the integration of computer science and mathematics education at 29%. Although single-subject studies still account for a significant proportion (24%), STEM education has gradually become a critical component of mathematics education, driving the widespread adoption of interdisciplinary teaching models, improving students' CT.

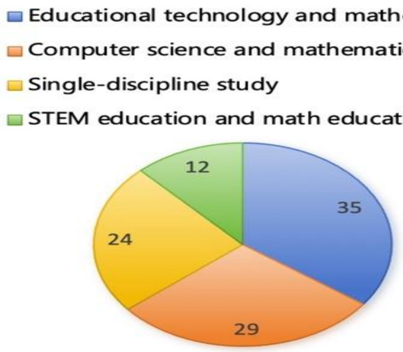


Figure 3
Integration of disciplines

**Intervention Strategies**

The instructional intervention strategies aimed at enhancing CT were extracted and consolidated from the 17 reviewed studies for comprehensive analysis. These strategies include MCTBML, PANGTUS, PBL, cooperative learning, VBA, Alan Hoffer's model, Scratch Programming Project, mind mapping, discovery learning, STEM education, assessment, the flipped classroom model, and ADDIE. The distribution of specific teaching intervention methods is illustrated in Figure 3.

Overall, one (6%) of the 17 articles employed an infusion approach, where students were encouraged to recognize CT and apply CT while engaging in classroom activities or completing mathematics tasks. Two (12%) articles didn't provide details on this aspect. The remaining 14 (82%) studies utilized the immersion approach, where CT skills were implicitly in the learning tasks and were not emphasized by instructors during teaching activities or problem-solving.

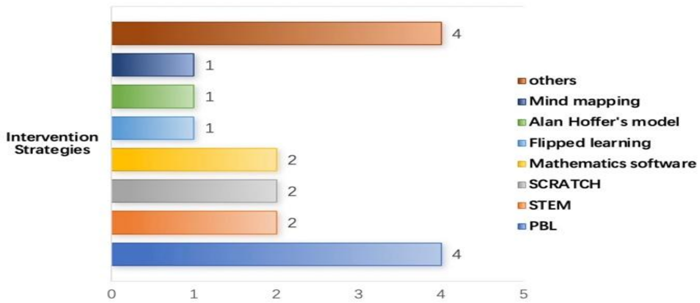


Figure 3
Intervention Strategies of the reviewed studies (Number of studies n=17)

Four (24%) articles employed the PBL model that allows students to acquire knowledge and new insights based on their experience, often through presentations. Through PBL, students engage in solving real problems, conducting investigations, and fostering inquiry-based learning (Setyarini et al., 2020). Zakaria et al. (2025)conducted an experimental study at a university to examine the effectiveness of the PBL model on students' CT, finding that PBL significantly increased the average scores across various CT indicator.

Technologically driven strategies, such as STEM integration and SCRATCH programming projects, each featured in 11.8% of the studies, highlight the growing trend of integrating technology and multidisciplinary approaches in education. These methods not only enhance students' technical proficiency but also foster innovative thinking by blending concepts across the fields of STEM. Additionally, the use of specialized mathematics software and flipped learning methodologies, each represented in 11.8% of the interventions, underscores the importance of innovative educational tools and teaching paradigms in increasing engagement and practical application skills during classroom interactions. Other singular strategies, such as Alan Hoffer's model and mind mapping, each accounting for 5.9% of the interventions, reflect a growing interest in experimenting with novel and potentially transformative educational practices. The "others" category, which includes a variety of less conventional strategies, further reinforces the fields commitment to pedagogical innovation.

The diverse interventions identified in this review not only demonstrate the field's adaptability to evolving educational demands but also emphasize the importance of continually diversifying teaching approaches. Ongoing exploration and rigorous evaluation of these methods are essential to fully understand their impact on enhancing undergraduates' CT. These efforts will inform the development of future pedagogical strategies and contribute to the body of literature on educational best practices.

**Creative Thinking Measures**

All seventeen studies provided definitions or general principles of CT, either based on researchers' own interpretations or in reference to established studies. The assessment methodologies employed in these studies reflected a wide range of approaches to evaluate the enhancement of CT within mathematics education. Notably, 88% of the studies utilized a blend of both standardized and non-standardized measures, while the remaining 12% replied solely on standardized assessments. The non-standardized measures, which constituted the majority, were predominantly task-oriented and included observational methods, semi-structured interviews, and specialized tests such as those derived from the Torrance Tests of Creative Thinking (TTCT). Additionally, customized tools like the Mathematics Creative Thinking Test (MCTS), an adaptation of the TTCT, were also developed and used. Standardized assessments, though less common, provided a rigorous CT evaluation framework. These tools were supplemented by qualitative methods, such as document analysis and open interviews, to offer a more comprehensive understanding of students' CT following the intervention.

In summary, the integration of diverse evaluative techniques across the studies highlights the necessity of a dual approach that combines both custom-designed and universally recognized testing methods in educational research. This comprehensive assessment strategy is crucial for fully understand the impact of various pedagogical interventions on the development of CT in undergraduate mathematics education.

### Reported Outcomes

All 17 studies reported a positive effect of the intervention strategies on improving CT. Four studies (23.5%) found that students in the experimental group, who received CT intervention strategies, showed a significantly greater improvement in compared to students in the control group, who were taught using traditional pedagogies such as lectures. Six studies (43%) conducted pre-tests and post-tests with a single group, reporting varying degrees of improvement in students' CT following the intervention.

Several studies also examined math achievements, such as understanding mathematical literacy, math concepts, student motivation, communication, and problem-solving of mathematics. Evendi et al. (2022), and Nadarajan et al. (2022) highlight the cognitive bridge between CT and the resolution of mathematical problems, noting a substantial and positive correlation between CT and students' academic performance.

## DISCUSSION

### The Role of Creative Thinking in Mathematics Education

Creative thinking (CT) is a fundamental component of modern mathematics education, significantly influencing students' problem-solving abilities, and cognitive flexibility. It enables students to approach mathematical challenges with innovation and confidence, fostering a deeper engagement with mathematical concepts (Rahayuningsih et al., 2023). CT is not merely an abstract concept but a cognitive process that encourages students to explore multiple problem-solving pathways, develop original solutions, and think beyond conventional mathematical procedures (Munakata et al., 2023). When students engage in creative problem-solving activities, their motivation for learning mathematics increases. A learning environment that fosters inquiry, curiosity, and open-ended exploration supports the sustained development of CT, allowing students to construct knowledge actively rather than passively absorb information (Wijaya et al., 2021). Students exposed to interdisciplinary instructional models demonstrate a notable improvement in generating innovative solutions, shifting from routine problem-solving to exploratory thinking.

Furthermore, the integration of digital tools in mathematics education enhances CT development. Studies incorporating dynamic mathematical software, computational programming (Agustina, 2024), and flipped learning environments indicate that students in technology-enhanced learning settings demonstrate greater flexibility in mathematical reasoning and creative exploration (Karakaya Cirit & Aydemir, 2023). Digital learning resources make students engage in mathematics beyond traditional classroom, fostering independent, inquiry-driven learning (Sbaih, 2023). The lack of standardized assessment tools for evaluating CT in digital learning environments presents a significant challenge, underscoring the need for validated frameworks to measure the effectiveness of digital interventions in fostering CT development.

### The Impact of Creative Thinking on Students' Mathematical Performance

The findings further establish that creative thinking positively influences students' academic performance in mathematics. A comparison between students engaged in CT-enhancing instructional models and those in traditional mathematics learning settings reveals that students exposed to CT-focused strategies demonstrate significantly higher mathematical understanding. The effectiveness of CT-enhancing methodologies lies in their ability to promote cognitive flexibility, divergent thinking, and strategic reasoning. Unlike traditional instruction, which prioritizes procedural fluency, CT-focused approaches require students to synthesize information, establish connections between mathematical concepts, and apply knowledge in novel situations (Ariani et al., 2022). Research further supports that interdisciplinary mathematics instruction enables students to explore mathematical concepts from multiple perspectives, leading to improved engagement and academic success (Jawad et al., 2021). However, this study's findings contrast with previous research suggesting that technology-assisted learning alone does not necessarily enhance students' mathematical performance (Setyarini et al., 2020). This discrepancy may be due to differences in instructional design and time allocation for creative learning activities. To maximize the potential of CT-focused learning, educators must ensure that students engage actively with mathematical concepts rather than passively interact with digital content.

### Future Research and Educational Implications

Despite the evident benefits of CT in mathematics education, several challenges remain in effectively integrating CT-enhancing instructional models into undergraduate curricula. A key limitation is the lack of longitudinal research investigating whether CT skills developed in undergraduate education persist in professional contexts. Future studies should examine the long-term impact of CT interventions, assessing whether students retain and apply their creative problem-solving skills beyond the classroom (Jebur, 2020). Another challenge is the absence of standardized assessment tools for evaluating CT in mathematics education. The reviewed studies use varied evaluation methods, including the Torrance Test of Creative Thinking (TTCT), Mathematics Creative Thinking Test (MCTS), and qualitative rubrics (Rohaeti et al., 2019). However, the lack of consistency in CT assessment methodologies hinders cross-study comparability. Future research should focus on developing validated, standardized assessment frameworks to ensure consistent measurement of CT outcomes across different instructional models. Additionally, comparative studies on CT-enhancing instructional approaches remain limited. While methodologies such as PBL, flipped learning, and Scratch programming have been independently examined, few studies have directly compared their effectiveness in fostering CT (Vlasenko et al., 2020). Future research should conduct controlled experimental studies to determine which instructional strategies lead to the most significant improvements in CT and how they can be effectively incorporated into undergraduate mathematics curricula. The findings of this study underscore the importance of creative thinking in shaping students' engagement, problem-solving abilities, and overall academic performance in mathematics. Moving away from procedural learning, CT-enhancing strategies encourage students to develop independent, flexible, and innovative mathematical reasoning skills. Despite advancements in CT-focused instructional approaches, several research gaps remain, particularly regarding longitudinal assessments of CT retention, the standardization of CT measurement tools, and comparative analyses of instructional methodologies. Addressing these challenges will contribute to a stronger theoretical and empirical foundation for CT in mathematics education.

## CONCLUSION

This systematic review examines interventions designed to enhance creative thinking (CT) in undergraduate mathematics education，synthesizing findings from 17 peer-reviewed studies indexed in Scopus and WoS. The analysis identifies three key trends: an increasing emphasis on fostering CT at the undergraduate level; the integration of technology-enhanced instructional methods, and the adoption of interdisciplinary approaches such as STEM and PBL. These findings indicate a pedagogical shift away from traditional rote learning toward student-centered, computationally integrated strategies that actively cultivate creativity and problem-solving skills.

Despite these advancements, several critical research gaps persist. First, the scarcity of longitudinal studies limits the understanding of how CT evolves over time and whether its benefits extend beyond short-term interventions. Second, the absence of standardized CT assessment frameworks restricts comparability across studies, underscoring the need for validated and widely accepted measurement tools. Third, there is a lack of comparative studies evaluating the effectiveness of different instructional interventions, hindering the development of evidence-based best practices. To address these gaps, future research should implement longitudinal studies to address the long-term impact of CT interventions, develop standardized assessment framework to ensure consistency in evaluating CT outcomes, and conduct comparative analyses to identify the most effective pedagogical approaches. Advancing research in these areas will contribute to a more robust theoretical and empirical foundation for CT in mathematics education, equipping students with the creativity in STEM fields and real-world applications.

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**Appendix A**
**A list of the 17 reviewed studies**

| Article Title | Author | Year | Source |
|---|---|---|---|
| 1.Learning to Promote Students' Mathematical Curiosity and Creativity | Rahayuningsih, S; Ikram, M; Indravati, N | 2023 | WoS |
| 2.Non-traditional assessments to match creative instruction in undergraduate mathematics courses | Munakata, M; Monahan, C; Krupa, E; Vaidya, A | 2023 | WoS |
| 3.Improving the Creative Thinking Skills of the Next Generation of Mathematics Teachers Using Dynamic Mathematics Software | Wijaya, TT; Zhou, Y; Ware, A; Hermita, N | 2021 | WoS |
| 4.Effects of Flipped Classroom on Calculus Performance and Mathematical creative thinking Skills of Higher Institution Students | Ramli，Mohd Shahridwan; Ayub, Ahmad Fauzi Mohd; Razali, Fazilah; Ghazali, Norliza | 2024 | Scopus |
| 5.Students' Creative Thinking Ability on Problems of Mathematics Literacy | Agustina, L. Zaenuri, Isnarto, Dwijanto, | 2024 | Scopus |
| 6.Online scratch activities during the COVID-19 pandemic: Computational and creative thinking | Cırıt, D. K. Aydemir, S. | 2023 | Scopus |
| 7.Development of a model of creative thinking based on mathematical literacy | Djam'an, N. Asrawati, N. Sappaile, B. I. Sidjara, S. | 2023 | Scopus |
| 8.Creative thinking in students of mathematics in universities and its relationship with some variables | Sbaih, A. D. | 2023 | Scopus |
| 9.The Impact of Android Module-Based Inquiry Flipped Classroom Learning on Mathematics Problem Solving and Creative Thinking Ability | Ariani, D. N. Sumantri, M. S. Wibowo, F. C. | 2022 | Scopus |
| 10.The Impact of Teaching by Using STEM Approach in The Development of Creative Thinking and Mathematical Achievement Among the Students of The Fourth Scientific Class | Jawad, L. F. Majeed, B. H. Alrikabi, H. T. S. | 2021 | Scopus |
| 11.Problem-based approach to develop creative thinking in students majoring in mathematics at teacher training universities | Vlasenko, K. Achkan, V.Chumak, O. Lovianova, I. Armash, T. | 2020 | Scopus |
| 12.The effect of project-based learning assisted PANGTUS on creative thinking ability in higher education | Setyarini, T. A. Mustaji, Jannah, M. | 2020 | Scopus |
| 13.Identification of instructional learning design by Alan Hoffer's model and its effect on students' creative thinking in mathematics | Jebur, A. M. | 2020 | Scopus |
| 14.Analysis and design of mathematics student worksheets based on PBL learning models to improve creative thinking | Umriani, F. Suparman, Hairun, Y. Sari, D. P. | 2020 | Scopus |
| 15.Development of stem integrated E-learning design to improve student's creative thinking capabilities | Wahyuaji, N. R.Suparman, | 2019 | Scopus |
| 16.Developing interactive learning media for school level mathematics through open-ended approach aided by visual basic application for excel | Rohaeti, E. E. Bernard, M.Primandhika, R. B. | 2019 | Scopus |
| 17.Cooperative Learning on Promoting Creative Thinking and Mathematical Creativity in Higher Education | Catarino, Paula; Vasco, Paulo; Lopes, José; Silva, Helena; Morais, Eva | 2019 | Scopus |