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MATHEMATICAL THINKING ABILITY: A LITERATURE REVIEW ON COGNITIVE STYLES AND THE PROBLEM-BASED LEARNING MODEL

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Abstract

This study explores the relationship between mathematical creative thinking, students' cognitive styles (Field Independent and Field Dependent), and the Problem Based Learning (PBL) model in solving open-ended problems. Using a Systematic Literature Review (SLR) based on the PRISMA framework, this research analyzed 15 relevant articles published between 2018 and 2025. The findings reveal that cognitive styles influence students' creative thinking patterns. Field Independent students tend to produce more original and flexible solutions, while Field Dependent students perform better with structured guidance. Moreover, PBL is effective in enhancing the dimensions of creative thinking—fluency, flexibility, originality, and elaboration—especially when combined with open-ended tasks. This review highlights the importance of adaptive instructional design that integrates PBL and accounts for students' cognitive styles to foster mathematical creative thinking skills.

Keywords: *Mathematical Creative Thinking, Cognitive Style, Problem Based Learning, Open-ended Problems, Systematic Literature Review.*

INTRODUCTION

Mathematical thinking ability constitutes a crucial competency in 21st-century education. One of the essential aspects of mathematical thinking in contemporary practice is mathematical creative thinking ability. This capability enables students to generate problem-solving approaches that are original, flexible, and value-added [1]. Creative thinking in mathematics not only reflects the extent to which students deeply understand concepts, but also the degree to which they can transform such understanding into innovative and applicable solutions across diverse contexts [2]. An individual's creativity is characterized by four principal indicators: fluency, flexibility, originality, and elaboration [3]. In the context of mathematics learning, these four aspects serve as observable indicators of mathematical creative

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thinking when students engage in solving open-ended problems.

Mathematical creative thinking ability requires a learning environment that provides opportunities for idea exploration, solution discovery, and active student engagement in the problem-solving process [4]. In this context, the Problem-Based Learning (PBL) approach emerges as a highly relevant and promising instructional model for fostering mathematical creative thinking ability [5]. Within the Problem-Based Learning process, students serve as the primary agents, as they are confronted with open-ended and contextual problems that allow for multiple solution pathways [6].

In the Problem-Based Learning process, students progress through several stages, including problem identification, information seeking, discussion, and reflection. These stages encourage students to think critically and creatively in designing as well as evaluating various alternative solutions. Research by Baetul ’Iza and Hesti Khasanah (2023) indicates that the consistent implementation of Problem-Based Learning is capable of enhancing students’ mathematical creativity indicators in solving open-ended problems. Furthermore, according to Anjelina et al. (2022), Problem-Based Learning can create a learning environment that stimulates students to continuously engage in divergent thinking and develop their metacognitive abilities in achieving a deeper understanding of mathematical concepts. Therefore, the integration of the development of creative thinking ability with the implementation of the Problem-Based Learning model is considered a strategic approach in mathematics education, aimed at equipping students with higher-order thinking skills essential for addressing the challenges of the 21st century [7].

The successful implementation of the Problem-Based Learning model is influenced by several factors, one of which is cognitive style [8]. Field Independent (FI) and Field Dependent (FD) cognitive styles can affect how students extract, process, and interpret information [9]. Students with a Field Independent cognitive style tend to be more analytical and autonomous, whereas those with a Field Dependent cognitive style rely more on contextual cues and external support. Yulianto et al. (2021) reported that Field Independent students demonstrate stronger aspects of mathematical creative thinking, such as fluency and analytical ability, compared to Field Dependent students. Although Field Dependent students also exhibit certain indicators of creativity, they tend to depend more on guidance. Furthermore, research conducted by Takdirmin and Mahmud (2023) indicates that the Field Independent cognitive style is more advantageous in developing complex and independent solutions in the context of open-ended problems, while the Field Dependent cognitive style shows better development when provided with clear structure and guidance.

Within the context of Problem-Based Learning influenced by cognitive style factors, the implementation of open-ended problems serves as a component that enriches the processes of exploration, investigation, and problem solving, both independently and collaboratively [10]. Furthermore, solving open-ended problems represents one of the most relevant approaches for developing

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students' mathematical creative thinking ability [11]. The resolution of open-ended problems enables students to present more than one method of solution. This aligns with the characteristics of creative thinking, which encompass the dimensions of fluency, originality, and elaboration [12].

Based on the aforementioned background and the need for a more comprehensive understanding of the dynamics of creative thinking ability in mathematics education—particularly involving variations in cognitive styles and the Problem-Based Learning model—the following research questions are formulated: (1) How is the implementation of the Problem-Based Learning model, when viewed from Field Independent and Field Dependent cognitive styles, in enhancing students' mathematical creative thinking ability?; (2) How does students' mathematical creative thinking ability, in relation to cognitive styles, manifest in solving open-ended problems?; (3) How does the Problem-Based Learning approach support the development of students' mathematical creative thinking ability in solving open-ended problems?

METHOD

The method employed in this study utilizes a Systematic Literature Review approach to comprehensively examine literature related to students' mathematical creative thinking ability in relation to cognitive styles and the Problem-Based Learning (PBL) approach, particularly within the context of solving open-ended problems. The selection of the Systematic Literature Review method is based on the objective of constructing a systematic synthesis of relevant and in-depth findings from previous studies, as well as identifying research gaps that may serve as a foundation for future investigations. The literature review process in this study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which consist of four main stages: identification, selection, eligibility assessment, and data synthesis.

Identification Stage

The identification stage was conducted by searching various databases, including Google Scholar, ScienceDirect, and SINTA. Article retrieval was carried out using the keywords "mathematical creative thinking ability," "cognitive style," "Problem-Based Learning," and "open-ended problem," with a publication year range from 2019 to 2025.

Selection Stage

At the selection stage, articles were screened based on the relevance of their titles and abstracts to the research focus. The selection criteria included peer-reviewed journal articles that addressed at least two of the three main focuses, namely mathematical creative thinking ability, Field Independent (FI) and Field Dependent (FD) cognitive styles, and the Problem-Based Learning model.

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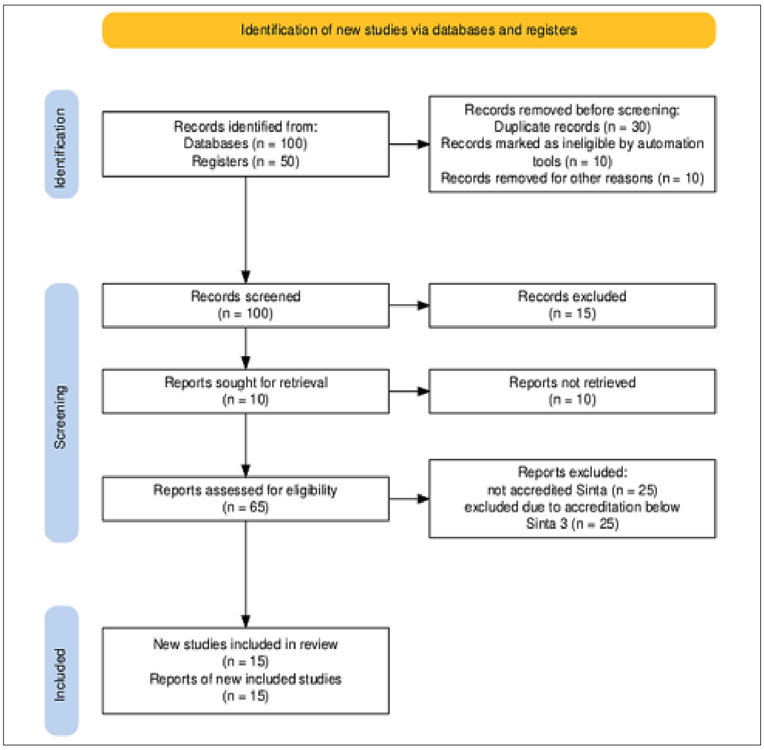

Figure 1. PRISMA Diagram Flow

In addition, the selected articles were limited to journals with a minimum accreditation of SINTA 3. This criterion was applied to ensure the quality and credibility of the sources included in the literature review. Accordingly, articles published in non-SINTA-accredited journals (n = 25) and those from journals with accreditation below SINTA 3 (n = 25) were excluded from the selection process. This exclusion process was conducted after the identification and initial screening stages to ensure that the analyzed articles originated from scientifically validated and quality-assured sources. Consequently, only articles that met the research topic criteria, had undergone a peer-review process, and were published in journals with at least SINTA 3 accreditation were advanced to the eligibility assessment stage.

Eligibility Assessment Stage

At the eligibility assessment stage, a comprehensive content analysis was conducted on the selected articles to ensure the alignment of methodology, context, and overall research quality.

Synthesis Stage

The final stage, data synthesis, was conducted thematically. Data from articles that met the criteria were organized into a table comprising key information such as authors, year of publication, research objectives, study subjects, methodologies employed, and principal findings. The synthesis was carried out based on three main analytical focuses: the relationship between cognitive styles and Problem-Based Learning, the relationship between cognitive styles and mathematical creative thinking ability,

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and the relationship between Problem-Based Learning and mathematical creative thinking ability in solving open-ended problems.

RESULTS AND DISCUSSION

Results

This study is based on the analysis and review of a number of relevant scientific articles, encompassing both national and international publications within the period of 2018 to 2025. The analyzed articles cover topics related to mathematical creative thinking ability, students' cognitive styles (Field Independent and Field Dependent), and the implementation of Problem-Based Learning, particularly in the context of solving open-ended problems. The results of the analysis, identification, and selection of articles are presented in the following table, which includes information on authors, year of publication, source of publication, and key findings.

Table 1. Percentage

Researcher	Source of Publication	Key Findings
[13]	MATHEMA JOURNAL	The results indicate that based on the GEFT test, among 28 eighth-grade students of SMP Muhammadiyah 1 Sumberpucung, 39.28% exhibited a Field Independent (FI) cognitive style, while 60.71% demonstrated a Field Dependent (FD) cognitive style. Four subjects with different cognitive styles were selected for interviews, namely I1, I2, D1, and D2, all of whom were categorized at level 3 of mathematical creative thinking ability (creative level). All four subjects fulfilled the indicators of fluency and flexibility but showed limitations in originality.
[14]	Jurnal Review Pembelajaran Matematika	The findings reveal that the thinking process of Field Independent students is conceptual in nature, whereas Field Dependent students tend to exhibit computational thinking processes.
[15]	*International Journal of Evaluation and Research in Education*	The study shows that educational level does not determine students' creativity levels; female students demonstrate higher creativity than male students, and visual learning styles are more supportive of creativity compared to kinesthetic and auditory styles.
[16]	EduMa : *Mathematics Education Learning and Teaching*	The results indicate that students' thinking processes in solving problems involving originality and elaboration are closely associated with the functions of the right and left brain hemispheres.
[17]	*Journal of Mathematics Education* (JME)	The findings show that students with a Field Dependent cognitive style are only able to represent certain models of mathematical problems, whereas Field Independent students are capable of representing all indicators of mathematical representation.
[18]	Indiktika : Jurnal Inovasi Pendidikan	The study demonstrates that the developed open-ended problems are valid based on expert review and can be

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Researcher	Source of Publication	Key Findings
	Matematika	utilized as an evaluation tool for students' mathematical creative thinking.
[19]	Prima: Jurnal Pendidikan Matematika	A practicality test conducted with sixth-grade students of SMPN 1 Kasihan showed a practicality level of 75%, indicating that the worksheet (LKS) is relatively easy for students to use.
[20]	*International Journal of Progressive Mathematics Education*	The study involved three students, each representing one aspect of creative thinking. Students demonstrating fluency were able to solve problems quickly and generate multiple answers; those exhibiting flexibility used various strategies to obtain more solutions; and those demonstrating originality produced unique answers distinct from others.
[21]	*European Journal of Educational Research*	The results indicate that the implementation of the Problem-Based Learning method effectively enhances students' critical and creative thinking abilities. Students are able to analyze problems effectively, solve cases with appropriate solutions, and become more active and challenged in the learning process.
[22]	*Journal of Mathematics Education*	The findings show that geometry instruction based on open-ended problem-based learning effectively improves students' fluency and flexibility in thinking.
[23]	*Pegem Journal of Education and Instruction*	The study indicates that both open-ended learning and creative problem-solving models influence students' creative thinking skills. In comparative analysis, the open-ended learning model is found to be more effective than creative problem solving and direct instruction.
[24]	*Frontiers in Neurorobotics*	This study develops an open-ended learning framework that enables students to learn to address new tasks without prior information and independently construct representations of tasks and environments for adaptation.
[25]	*International Journal of Instruction*	The results show that students in the experimental class achieved a higher improvement in scientific work ability (N-Gain = 71%) compared to the control class (43%). Additionally, the level of scientific performance in the experimental class was categorized as very good (72%), whereas the control class achieved only 53%.
[26]	JTAM : Jurnal Teori dan Aplikasi Matematika	The findings indicate that all tested learning models positively impact students' mathematical problem-solving ability. However, the Problem-Based Learning model yields better results compared to Discovery Learning and Open-Ended Learning.
[27]	Qalamuna – Jurnal Pendidikan, Sosial, dan Agama	The literature review reveals that the most influential factors in enhancing creative thinking ability are the Problem-Based Learning model and the open-ended learning approach.

Discussion

Based on the review of 15 analyzed articles, several significant

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patterns of relationships were identified among mathematical creative thinking ability, cognitive styles, and Problem-Based Learning, particularly in the context of solving open-ended problems.

The Relationship between Cognitive Styles and Mathematical Creative Thinking Ability

Cognitive style constitutes an external factor that influences how students acquire, process, and utilize information and knowledge during the learning process. Based on the reviewed studies, Field Independent and Field Dependent cognitive styles exhibit differing implications for the development of mathematical creativity. Research conducted by Amanah and Inganah (2025) indicates that students with a Field Independent cognitive style tend to be more autonomous in their thinking, capable of exploring diverse problem-solving strategies, and demonstrate flexibility and fluency in solving open-ended problems. In contrast, students with a Field Dependent cognitive style tend to require greater guidance during the exploration process; however, they still possess the potential to achieve a high level of creativity when supported by appropriate instructional approaches. These findings are further supported by Mawardi et al. (2020), who argue that Field Independent students are more inclined toward conceptual thinking, whereas Field Dependent students rely more heavily on computational procedures. This aligns with the notion that creativity in mathematics is not solely concerned with producing correct answers, but also with the ability to develop meaningful and valuable approaches to problem-solving. Furthermore, Sobirin et al. (2025) emphasize that the mathematical representations produced by Field Independent students tend to be more complex compared to those of Field Dependent students, who are generally able to represent only partial aspects of a given problem situation.

The Influence of Problem-Based Learning on the Development of Mathematical Creative Thinking Ability

The Problem-Based Learning model is effective in fostering the development of mathematical creative thinking ability. In its implementation, students are positioned as active subjects who are confronted with contextual and open-ended problems, thereby stimulating the generation of diverse solution strategies. Studies conducted by Tanjung et al. (2020) and Suastika et al. (2024) demonstrate that Problem-Based Learning can significantly enhance the dimensions of fluency and flexibility. Furthermore, research by Kartikasari et al. (2022) indicates that the integration of Problem-Based Learning with open-ended problem-solving holds substantial potential for improving all indicators of mathematical creative thinking ability. This is also consistent with the findings of Doncieux et al. (2018), who emphasize that open-ended problem-based learning not only promotes mathematical creative thinking but also supports students' adaptive capacity in responding to new challenges.

The Relationship between Cognitive Styles and Problem-Based Learning

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in the Context of Open-Ended Problems

The interrelationship among cognitive styles, Problem-Based Learning, and open-ended problems lies in their capacity to create a learning environment that fosters exploration and originality. Open-ended problems provide opportunities for students to express diverse thinking styles and cognitive preferences. Studies by Saida et al. (2021) and Akbar et al. (2021) indicate that when students are presented with contextual open-ended problems, they exhibit responses reflecting different indicators of mathematical creative thinking ability. Students with a Field Independent cognitive style tend to demonstrate stronger responses in terms of originality and elaboration, whereas those with a Field Dependent cognitive style exhibit greater strategic flexibility when supported through collaboration. An important implication of these findings is that teachers need to design instructional strategies grounded in responsive teaching, which accommodates students' individual thinking styles through flexible activity design. As highlighted by Juwita et al. (2019), such approaches can serve as effective means to promote both independent exploration and group discussion. Furthermore, findings from Musdi et al. (2024) reveal that external factors such as gender and learning styles also influence the quality of creative thinking, thereby opening opportunities for richer pedagogical interventions, including the use of visual media, interactive simulations, and manipulative tools.

Contribution and Research Gaps

The Problem-Based Learning model, when combined with students' cognitive styles and the integration of open-ended problems, represents an approach that is responsive to 21st-century learning demands, particularly in fostering creativity, problem-solving, and reflective thinking. However, several research gaps remain that warrant further investigation. First, most studies have not explicitly examined the interaction between cognitive styles and the stages of Problem-Based Learning within mathematics instruction. Second, although some studies have distinguished between the effects of Field Independent and Field Dependent cognitive styles, there is still a lack of longitudinal research evaluating how these differences contribute to the development of mathematical creativity over time.

CONCLUSION

Based on the systematic review of 15 relevant articles, it can be concluded that students' mathematical creative thinking ability is significantly influenced by cognitive styles and the instructional models employed, particularly Problem-Based Learning (PBL). Problem-Based Learning has been proven effective in enhancing the dimensions of mathematical creative thinking, including fluency, flexibility, originality, and elaboration. It provides contextual learning experiences, encourages the exploration of diverse solutions, and promotes active student engagement in higher-order thinking processes. Furthermore, the use of open-ended problems within the context of Problem-Based Learning enriches the learning process by providing opportunities for students to

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express creative ideas, engage in divergent thinking, and develop a deeper conceptual understanding.

The practical implications of these findings highlight the need to develop mathematics instructional strategies that are not solely focused on content delivery, but also provide opportunities for the development of students' cognitive potential and creativity. Accordingly, this study recommends the implementation of instructional models that take into account students' cognitive characteristics, along with the systematic use of open-ended problems to foster mathematical creative thinking ability.

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