

THE INTERACTION OF PROBLEM BASED LEARNING AND COGNITIVE STYLES ON STUDENTS' MATHEMATICAL CREATIVE THINKING ABILITY

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ABSTRACT

This study examines the interaction between the Problem Based Learning (PBL) model and students' cognitive styles in influencing mathematical creative thinking ability. A quasi-experimental design with a 2×2 factorial arrangement was employed, involving third-semester students of the Mathematics Education Department at Universitas Sebelas April. The experimental group (23 students) received instruction through PBL, while the control group (22 students) learned through conventional methods. Instruments included a mathematical creative thinking test and the Group Embedded Figures Test (GEFT) to identify Field Independent (FI) and Field Dependent (FD) styles. The results indicate three key findings: (1) PBL significantly outperforms conventional learning in enhancing mathematical creative thinking; (2) students with FI style show higher creative thinking scores compared to FD students; and (3) a significant interaction exists between learning model and cognitive style. Notably, PBL proves more effective for FI learners who benefit from its analytical and problem-oriented approach. These findings suggest that integrating PBL with consideration of students' cognitive styles can better foster mathematical creative thinking. Lecturers are encouraged to design instruction that adapts to cognitive diversity, ensuring optimal learning outcomes in mathematics education.

Keywords: interaction, problem based learning, cognitive style, mathematical creative thinking, field independent, field dependent

INTRODUCTION

The rapid development of science and technology in the 21st century requires higher education graduates to acquire higher-order thinking skills, one of which is the ability to think creatively in mathematics. Such ability is essential for students to design multiple problem-solving strategies, generate innovative ideas, and link mathematical concepts to real-life situations. However, mathematics instruction at the university level often remains dominated by procedural exercises and rote memorization. This conventional pattern tends to limit students' creativity and reduces the level of challenge in learning.

The Transformation Geometry course plays a pivotal role in cultivating mathematical creative thinking. The subject not only involves mastery of concepts such as translation, rotation, reflection, and dilation, but also demands skills in visualizing transformations, connecting patterns, and generalizing outcomes. Rahmayanti, Pasaribu, Gustiningsi, and Nusantara (2025) report that many transformation geometry classes in Indonesia still rely heavily on lecture-based methods, which lead students to be passive and less engaged. In fact, transformation

geometry offers rich potential for nurturing creativity since it requires the integration of logical reasoning, spatial intuition, and visual representation.

Problem Based Learning (PBL) is one instructional model believed to address these challenges. PBL uses contextual problems as the starting point of learning and guides students to seek solutions through critical and creative thinking processes. Maulidia, Saminan, and Zainal Abidin (2020) emphasize that PBL provides space for students to explore different problem-solving approaches, trigger new ideas, and build confidence in presenting mathematical arguments. Furthermore, its emphasis on authentic problems facilitates collaboration, group discussion, and open-ended problem-solving—features that are highly relevant to transformation geometry instruction.

In addition to the learning model, students' cognitive styles are equally important. Arifin (2020) explains that Field Independent (FI) students are more analytical, able to extract relevant information from background contexts, and prefer working independently, whereas Field Dependent (FD) students tend to process information globally, require guidance, and feel more comfortable in collaborative settings. These characteristics influence how students process information, develop problem-solving strategies, and express their mathematical creativity. Within a PBL environment, such cognitive diversity may create distinctive dynamics: FI students are likely to excel in organizing ideas individually, while FD students may benefit more from the group-based nature of PBL.

Although numerous studies have examined the effectiveness of PBL and the influence of cognitive styles separately, research that combines both to enhance mathematical creative thinking in university-level Transformation Geometry courses remains limited. Previous works have generally focused on general problem-solving or critical thinking in secondary education, rather than on students' mathematical creativity when tackling complex topics such as transformation geometry. Based on this gap, the present study aims to:

1. Examine the influence of Problem Based Learning on students' mathematical creative thinking in the Transformation Geometry course.
2. Investigate the effect of cognitive styles on students' mathematical creative thinking in the same course.
3. Explore the interaction between instructional model and cognitive style in shaping students' mathematical creative thinking ability.

The findings are expected to contribute theoretically to the design of mathematics learning that accommodates students' cognitive diversity and practically to assist lecturers in creating sustainable learning environments that foster mathematical creativity. Moreover, the results may provide valuable insights for curriculum designers and higher education policymakers in strengthening mathematics instruction to meet the demands of the 21st century.

THEORETICAL FRAMEWORK

1. Mathematical Creative Thinking Ability

Mathematical creative thinking refers to the capacity to generate multiple ideas or novel solutions in addressing mathematical problems, highlighting originality, flexibility, fluency, and elaboration. Rahmayanti, Pasaribu, Gustiningsi, and Nusantara (2025) describe four core indicators of this ability: (1) Fluency, the skill to produce many correct responses or alternative strategies in a relatively short time; students with high fluency can easily propose varied problem-solving approaches. (2) Flexibility, the competence to shift perspectives or switch strategies when encountering difficulties; flexible students can adapt their methods to suit different problem contexts. (3) Originality, the ability to present rare, unique, and unconventional yet valid solutions, such as through uncommon visual representations or transformations. (4) Elaboration, the capacity to refine and expand ideas systematically, including providing detailed reasoning, supportive arguments, or well-developed diagrams and tables. These four indicators are complementary: fluency and flexibility provide variety, originality ensures novelty, and elaboration demonstrates depth of thought. Rahmayanti et al. (2025) emphasize that developing all four dimensions is essential for enhancing students' mathematical creativity and understanding.

Putra et al. (2020) add that mathematical creative thinking allows students to construct innovative and profound strategies in problem-solving. A meta-analysis by Zulnaldi et al. (2022) confirmed that problem-based instruction significantly improves mathematical creativity across different contexts. Suherman (2022) also highlights the need for systematic practice so that students become accustomed to producing diverse and original ideas. Thus, mathematical creative thinking is not only vital for solving complex mathematical tasks but also for fostering innovation and adaptability in today's learning environment.

2. Problem Based Learning (PBL)

Problem Based Learning (PBL) is an instructional model that employs authentic problems as a context for students to learn critical thinking, problem-solving, and essential knowledge. It is widely recognized as a promising approach to foster mathematical creative thinking because it places learners in real-world problem situations that require independent and collaborative exploration (Suryanti, Prihatnawati, & Purwanto, 2023). Hidayat and Sumarmo (2018) argue that PBL encourages students to identify problems, formulate hypotheses, and design creative alternatives for solutions. Similarly, Nurlaila, Nurlaelah, and Rohaeti (2021) show that the level of scaffolding in PBL influences students' flexibility and originality. Bron and Prudente (2024) further demonstrate that PBL leads to significantly greater gains in mathematical creativity compared to conventional learning. Masitoh (2025) affirms that PBL effectively encourages students to integrate diverse problem-solving strategies and mathematical concepts. Maulidia,

Saminan, and Zainal Abidin (2020) also point out that PBL provides a platform for students to explore ideas and spark creativity, making it highly relevant in developing mathematical creative thinking. The general syntax of PBL includes: (1) problem orientation, (2) organizing learning tasks, (3) independent and group investigation, (4) developing and presenting results, and (5) reflection and evaluation. The strength of PBL lies in promoting active participation, collaboration, and self-directed learning, which are crucial for enhancing students' mathematical creative thinking.

3. Cognitive Styles: Field Independent and Field Dependent

Cognitive style refers to the characteristic way an individual perceives, processes, and responds to information. In mathematics education, two styles frequently studied are Field Independent (FI) and Field Dependent (FD). FI individuals are typically analytical, autonomous, and capable of extracting relevant details from complex contexts, while FD individuals rely more on external cues and social interactions (Zhang & Sternberg, 2016; García-Ros et al., 2021). These differences may affect how students approach creative mathematical tasks, since varied cognitive processes often yield different problem-solving strategies. Lestari and Hendriana (2017) reported that FI students generally outperform FD students in mathematical creative thinking because they can structure information and propose original solutions. This is consistent with Rofiah et al. (2022), who found a positive link between FI style, creativity, and problem-solving ability.

4. The Relationship among PBL, Cognitive Styles, and Mathematical Creative Thinking

Integrating PBL with consideration of students' cognitive styles is believed to strengthen the development of mathematical creative thinking. PBL, which emphasizes independent analysis, may advantage FI students, while its collaborative and discussion-based nature can benefit FD students through the exchange of ideas. Previous studies indicate that the effectiveness of PBL in enhancing creativity depends greatly on students' cognitive styles. Maulidia et al. (2020) and Arifin (2020) reveal that the interaction between instructional models and cognitive styles significantly affects students' mathematical creativity. Hasibuan and Suryadi (2019) found that FI students show greater improvement in creativity through PBL compared to FD students, as FI learners are more independent and analytical in processing information. Fitriani and Hidayat (2023) also highlight that the effectiveness of PBL will be maximized if lecturers recognize students' cognitive characteristics. Similarly, Nurhasanah and Widyastuti (2022) argue that PBL design must be adapted to cognitive styles so that FD students can also benefit optimally. Collectively, these findings underline that combining PBL with awareness of cognitive styles is a key factor in fostering mathematical creative thinking.

5. Conceptual Framework and Hypotheses

Based on the above review, it can be conceptualized that both PBL and cognitive styles jointly influence students' mathematical creative thinking ability in

the Transformation Geometry course. While PBL provides challenging experiences that stimulate creative thinking, cognitive styles determine how students respond to such challenges. Therefore, the study proposes the following hypotheses:

1. The Problem Based Learning model has a positive effect on students' mathematical creative thinking, with differences in test results between students taught with PBL and those taught with conventional methods.
2. Cognitive style influences students' mathematical creative thinking, with differences in test results between FI and FD students.
3. There is an interaction effect between instructional models and cognitive styles on students' mathematical creative thinking in the Transformation Geometry course.

RESEARCH METHODOLOGY

This study employed a quantitative approach with a quasi-experimental design using a 2×2 factorial structure. The first factor was the instructional model, consisting of Problem Based Learning (PBL) and conventional teaching, while the second factor was cognitive style, namely Field Independent (FI) and Field Dependent (FD). The factorial design enabled examination of the individual effects of each factor as well as their interaction on students' mathematical creative thinking ability (Sugiyono, 2019).

The research population consisted of all students enrolled in the Mathematics Education Study Program at Universitas Sebelas April. From this population, third-semester students were selected using a cluster random sampling technique based on existing class divisions. The experimental group (Class A) consisted of 23 students who received instruction through PBL, while the control group (Class B) included 22 students who were taught using conventional methods. Each group was further classified by cognitive style (FI or FD), producing four treatment combinations: (1) PBL–FI, (2) PBL–FD, (3) Conventional–FI, and (4) Conventional–FD. This grouping follows Creswell's (2014) recommendation that sampling in quasi-experimental studies may utilize existing class structures as long as the groups are initially comparable.

The variables of this research included independent variables (instructional model: PBL and conventional; cognitive style: FI and FD) and the dependent variable (students' mathematical creative thinking ability in the Transformation Geometry course). The instruments comprised a Mathematical Creative Thinking Test, presented in essay form, designed to measure fluency, flexibility, originality, and elaboration in solving geometry transformation problems. The test was developed based on the indicators of mathematical creative thinking (Rahmayanti et al., 2025) and validated through expert judgment and limited pilot testing. In addition, the Group Embedded Figures Test (GEFT) was administered to classify students as either

FI or FD, following the standard procedures widely adopted in mathematics education research (Witkin et al., 2002).

Data analysis was conducted in several stages: (1) Assumption testing, including normality and homogeneity tests, to ensure data suitability for variance analysis (Santoso, 2020). (2) Two-way Analysis of Variance (ANOVA) to examine the main effects of instructional model (PBL vs. conventional), the effects of cognitive style (FI vs. FD), and the interaction effect between instructional model and cognitive style on mathematical creative thinking ability. Post hoc tests such as Tukey's test were conducted if significant interactions were identified. This method was chosen as it aligns with the objectives of the study, namely to analyze the effects of PBL, cognitive style, and their interaction on students' mathematical creative thinking (Creswell, 2014; Sugiyono, 2019).

RESULTS AND DISCUSSION

1. Identification of Students' Cognitive Styles

Students' cognitive styles were classified using the Group Embedded Figures Test (GEFT). The results are presented in Table 1.

Table 1. Identification of Students' Cognitive Styles

Group	Total Students	Field Independent (FI)	Field Dependent (FD)
Experimental (PBL)	23	9	14
Control (Conventional)	22	8	14
Total	45	17	28

The table shows that the experimental group, which received Problem Based Learning (PBL), consisted of 9 students with FI cognitive style and 14 students with FD style. Meanwhile, the control group taught with conventional methods included 8 FI and 14 FD students. In total, out of 45 participants, 17 students (37.8%) were identified as FI and 28 students (62.2%) as FD.

This distribution suggests that FD students were more dominant across both groups. This finding aligns with Arifin (2020), who reported that within mathematics learning contexts, FD students often outnumber FI students. Such predominance is noteworthy since FD learners generally require more guidance and collaboration, which may influence how they develop mathematical creative thinking (Maulidia, Saminan, & Zainal Abidin, 2020).

The cognitive style distribution also provides an initial picture of potential interactions between instructional models and students' cognitive styles. In the experimental group, the majority FD students (14 individuals) were expected to still develop their creative mathematical thinking skills, given that PBL emphasizes group work, discussion, and open-ended problem-solving, factors that tend to support FD

learners (Maulidia et al., 2020). On the other hand, the presence of FI students, both in the experimental group (9) and the control group (8), is important since FI learners are typically more analytical and independent. They are likely to consistently demonstrate higher levels of creative mathematical thinking under both instructional models, although PBL offers broader opportunities for exploration (Rahmayanti et al., 2025). This initial distribution sets the stage for further analysis using two-way ANOVA to test:

- a. Whether there are differences in mathematical creative thinking ability between students taught with PBL and those taught conventionally.
- b. Whether there are differences in mathematical creative thinking ability between FI and FD students.
- c. Whether there is an interaction effect between instructional model and cognitive style on mathematical creative thinking ability.

2. Descriptive Data of Mathematical Creative Thinking Ability

The descriptive data provide an overview of students' mathematical creative thinking ability across instructional models and cognitive styles. The results are presented in Table 2.

Table 2. Descriptive Statistics of Mathematical Creative Thinking Ability

Instructional Model	Cognitive Style	N	Mean	SD
Problem Based Learning (PBL)	Field Independent (FI)	9	80.56	8.08
	Field Dependent (FD)	14	60.71	8.29
	Total	23	68.48	12.74
Conventional	Field Independent (FI)	8	59.38	6.78
	Field Dependent (FD)	14	58.57	6.33
	Total	22	58.86	6.35
Overall Total	FI	17	70.59	13.10
	FD	28	59.64	7.32
	Total	45	63.78	11.14

Overall, students taught through PBL demonstrated higher scores in mathematical creative thinking than those taught conventionally. The total mean score for the PBL group was 68.48 (SD = 12.74), compared to 58.86 (SD = 6.35) for the conventional group. This initial difference suggests that PBL encourages students to produce more diverse, flexible, and in-depth mathematical ideas.

From the perspective of cognitive styles, FI students generally scored higher than FD students. Across both instructional models, FI students had an average of 70.59 (SD = 13.10), while FD students averaged only 59.64 (SD = 7.32). This indicates

that the independence and analytical traits of FI students contribute positively to their creative mathematical thinking.

The most notable finding appears when instructional models are combined with cognitive styles. The PBL–FI group achieved the highest average score of 80.56 (SD = 8.08), showing that FI students benefited the most from PBL. The PBL–FD group scored 60.71 (SD = 8.29), which was still higher than most conventional groups but substantially lower than PBL–FI. Meanwhile, both conventional–FI (59.38, SD = 6.78) and conventional–FD (58.57, SD = 6.33) groups had nearly similar averages.

In summary, the descriptive data reinforce the tendency that PBL particularly benefits FI learners. FI students appeared to leverage the problem-based environment to express mathematical ideas that were original, flexible, and detailed. By contrast, FD students may require additional support or strategies to fully maximize the benefits of PBL.

3. Test of Normality

After obtaining a general overview through descriptive statistics, the next step was to examine the normality of data distribution. Normality testing was conducted on the standardized residuals of mathematical creative thinking scores for each combination of instructional model and cognitive style using the Shapiro–Wilk test. The results are presented in Table 3.

Table 3. Test of Normality for Mathematical Creative Thinking Scores

Instructional Model	Cognitive Style	N	Shapiro–Wilk Statistic	Sig. (p)
PBL	Field Independent (FI)	9	0.848	0.071
PBL	Field Dependent (FD)	14	0.901	0.118
Conventional	Field Independent (FI)	8	0.930	0.512
Conventional	Field Dependent (FD)	14	0.924	0.253

The table shows that all groups obtained significance values above 0.05. Specifically, the PBL–FI group had $p = 0.071$, PBL–FD $p = 0.118$, Conventional–FI $p = 0.512$, and Conventional–FD $p = 0.253$. These values indicate that the mathematical creative thinking scores in each instructional model–cognitive style combination were normally distributed.

4. Test of Homogeneity of Variances

After confirming normality, the next step was to test the homogeneity of variances, i.e., whether the variance of mathematical creative thinking scores was equal across groups. Levene’s Test was applied, and the results are summarized in Table 4.

Table 4. Test of Homogeneity of Variances for Mathematical Creative Thinking Scores

Basis of Calculation	Levene Statistic	df1	df2	Sig. (p)
Based on Mean	0.256	3	41	0.857
Based on Median	0.190	3	41	0.903
Based on Median and with adjusted df	0.190	3	31.248	0.902
Based on Trimmed Mean	0.267	3	41	0.849

All significance values (p) were greater than 0.05 ($p = 0.857, 0.903, 0.902$, and 0.849). This result indicates that no significant differences in variances existed among groups, meaning that the assumption of homogeneity of variances was satisfied. Thus, the data met the requirements to proceed with two-way ANOVA.

5. Two-Way ANOVA

Having satisfied the assumptions of normality and homogeneity, the analysis proceeded with two-way ANOVA to test the effects of instructional model, cognitive style, and their interaction on students' mathematical creative thinking ability. The results are presented in Table 5.

Table 5. Results of Two-Way ANOVA for Mathematical Creative Thinking Ability

Source of Variation	Type III Sum of Squares	df	Mean Square	F	Sig. (p)	Partial Eta Squared
Model (Instructional)	1.435,43	1	1.435,43	26.06	< 0.001	0.389
Cognitive Style	1.124,66	1	1.124,66	20.42	< 0.001	0.332
Model × Cognitive Style	956.37	1	956.37	17.36	< 0.001	0.297
Error	2.258,38	41	55.08	–	–	–
Corrected Model	3.199,40	3	1.066,46	19.36	< 0.001	0.586

Note: $R^2 = 0.586$; Adjusted $R^2 = 0.556$.

The results show that the instructional model had a significant effect on students' mathematical creative thinking ability ($F = 26.06, p < 0.001$). The partial eta squared of 0.389 represents a large effect size, indicating that approximately 38.9% of the variance in mathematical creative thinking ability was explained by the instructional model.

Cognitive style also had a significant effect ($F = 20.42, p < 0.001$), with a partial eta squared of 0.332 (large effect). This suggests that students with Field Independent (FI) style demonstrated higher levels of mathematical creative thinking compared to Field Dependent (FD) students.

Furthermore, there was a significant interaction between instructional model and cognitive style ($F = 17.36, p < 0.001$), with a partial eta squared of 0.297 (large

effect). This indicates that the impact of instructional model on creative mathematical thinking varied depending on students' cognitive style.

Overall, the combined model (instructional model, cognitive style, and their interaction) accounted for 58.6% of the variance in mathematical creative thinking ability ($R^2 = 0.586$).

These findings confirm that Problem Based Learning (PBL) significantly enhances mathematical creative thinking compared to conventional methods. This result supports earlier research (Rahmayanti et al., 2025), which highlighted PBL's effectiveness in stimulating creative thinking through collaborative and open-ended problem-solving.

Additionally, cognitive style was found to play a critical role in learning outcomes. FI students were more analytical and independent, enabling them to better organize information and generate original solutions, consistent with findings by Arifin (2020) and Maulidia, Saminan, & Zainal Abidin (2020). Most importantly, the significant interaction suggests that the effectiveness of PBL is not uniform across all students; rather, it is strongly influenced by their cognitive style.

6. Plot of Estimated Marginal Means

To better understand the relationship between instructional model and cognitive style, the analysis was extended by presenting the plot of Estimated Marginal Means (EMM) for mathematical creative thinking scores. This plot illustrates the adjusted marginal means based on the results of the two-way ANOVA.

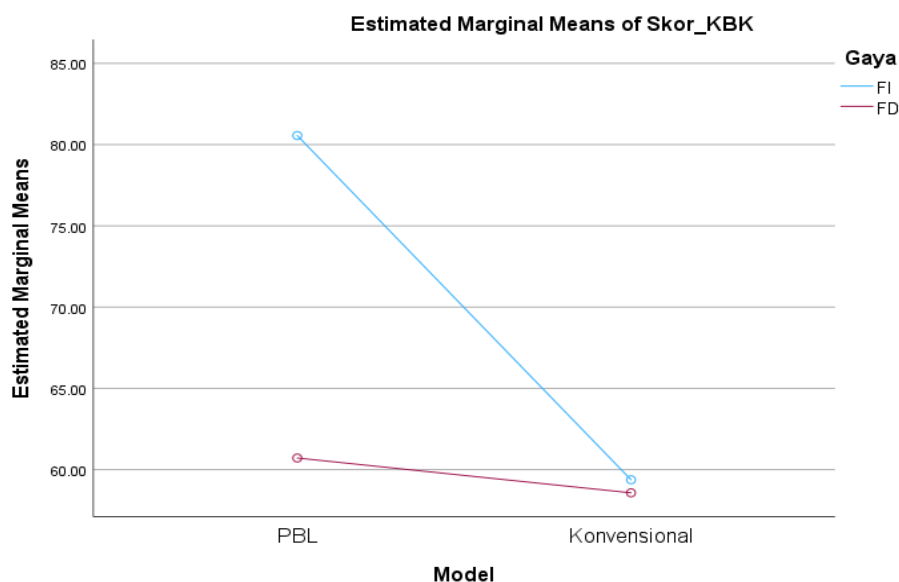


Figure 1. Plot of Estimated Marginal Means

Description of the plot:

- The X-axis represents the instructional model (Problem Based Learning and Conventional).
- The Y-axis represents the adjusted marginal means of mathematical creative thinking scores.

- Two lines represent cognitive styles: Field Independent (FI) and Field Dependent (FD).

From the plot, it can be observed that:

- The FI group under PBL obtained the highest marginal mean, around 80, while FI students under the conventional model scored around 59.
- The FD group displayed nearly identical marginal means across both instructional models, approximately 60.
- The two lines did not actually cross; however, they converged slightly on the conventional side and diverged on the PBL side. This pattern indicates a genuine interaction, even though the lines do not intersect sharply.

This pattern confirms that the effectiveness of Problem Based Learning is particularly strong among Field Independent students, while its impact on Field Dependent students is relatively minor. Although the lines in the plot did not intersect, the different slopes clearly suggest that the instructional model's effect varied according to cognitive style. This visual evidence aligns with the significant two-way ANOVA result ($F = 17.36$; $p < 0.001$; partial eta squared = 0.297).

The visualization through the EMM plot reinforces the ANOVA findings in a more intuitive way. Although the lines did not sharply cross, the difference in slope demonstrates that the effect of Problem Based Learning (PBL) was not uniform across cognitive styles. Field Independent students achieved substantially higher mathematical creative thinking scores under PBL compared to conventional learning. Conversely, Field Dependent students achieved relatively similar scores under both models.

These findings are consistent with Maulidia, Saminan, and Zainal Abidin (2020), who argued that FI learners tend to be more analytical and independent, thus better suited to problem-based environments that require exploration and decision-making. Similarly, Rahmayanti, Pasaribu, Gustiningsi, and Nusantara (2025) emphasized that PBL promotes mathematical creative thinking through open-ended problem-solving, group discussion, and self-reflection. In other words, PBL provides cognitive challenges that align well with the strengths of FI students, particularly their ability to structure information and generate original solutions.

On the other hand, FD students tend to rely more heavily on guidance and social support (Arifin, 2020). As a result, their mathematical creative thinking scores did not improve significantly under PBL compared to conventional learning. This highlights the importance of providing additional scaffolding or structured support when applying PBL to FD students to fully optimize their creative potential.

Overall, the combination of quantitative ANOVA findings and the visual pattern from the Estimated Marginal Means plot underscores that the interaction between instructional model and cognitive style is a key factor in enhancing students' mathematical creative thinking ability, particularly in the context of Transformation Geometry.

CONCLUSIONS AND IMPLICATIONS

1. Conclusions

Based on the findings regarding the effects of the Problem Based Learning (PBL) model and cognitive styles on students' mathematical creative thinking ability in the Transformation Geometry course, several conclusions can be drawn:

a. Significant Effect of Learning Model

Students taught through Problem Based Learning demonstrated higher mathematical creative thinking ability than those taught with conventional methods. This was confirmed by the two-way ANOVA result ($F = 26.06$; $p < 0.001$) with a partial eta squared value of 0.389, indicating a large effect size.

b. Significant Effect of Cognitive Style

Students with a Field Independent (FI) cognitive style achieved better mathematical creative thinking performance than their Field Dependent (FD) peers ($F = 20.42$; $p < 0.001$; partial eta squared = 0.332).

c. Significant Interaction

There was a significant interaction between the learning model and cognitive style ($F = 17.36$; $p < 0.001$; partial eta squared = 0.297). The Estimated Marginal Means plot showed that PBL was most effective for FI students, while FD students experienced little to no improvement under PBL compared to conventional learning.

2. Implications

The results of this study provide important implications, both theoretically and practically:

a. Theoretical Implications

This research reinforces constructivist learning theory and the concept of cognitive style differences in influencing the success of problem-based instruction. The findings highlight that mathematical creative thinking ability is shaped not only by instructional models but also by learners' cognitive styles.

b. Practical Implications

1) Instructional Design

Mathematics education lecturers, particularly in the Transformation Geometry course, are encouraged to apply Problem Based Learning as a primary instructional approach.

2) Differentiated Strategies

Since FD students gain fewer benefits from PBL, additional scaffolding strategies such as peer tutoring, structured guidance, and the use of visual media or concrete examples should be incorporated to help them optimize their mathematical creative thinking ability.

3) Curriculum Development and Teacher Training

The findings may serve as a foundation for curriculum revisions and professional development programs, ensuring that PBL is implemented

consistently while also accounting for cognitive style differences among students.

c. Directions for Future Research

Further studies could broaden the scope by including additional variables such as learning motivation, self-efficacy, or critical thinking skills. Future research may also examine the application of PBL in other mathematics courses or at different levels of education.

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