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The Effectiveness of the DOCAR Learning Model in Enhancing Students' Mathematical Creative Thinking: A Concurrent Embedded Mixed Methods Study Based on Self-Efficacy

Alfina Damayanti[1], Shoffan Shoffa[2], Febriana Kristanti[3]

[1,2,3] Mathematics Education Study Program, Muhammadiyah University of Surabaya, Indonesia

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ABSTRACT

Developing students' mathematical creative thinking is a key objective of twenty-first-century mathematics education. However, previous studies have generally examined innovative learning models and self-efficacy separately, providing limited evidence of their interaction in enhancing mathematical creative thinking. This study investigated the effectiveness of the DOCAR (Do, Observation, Construction, Association, Reflection) learning model in improving students' mathematical creative thinking across different levels of self-efficacy. A Concurrent Embedded Mixed Methods design was employed, with quantitative data as the primary source and qualitative data used to explain the quantitative findings. The study involved Grade VII students at SMP Muhammadiyah 15 Surabaya using a quasi-experimental non-equivalent control group design. Data was collected through mathematical creative thinking tests, self-efficacy questionnaires, classroom observations, students' written work, and semi structured interviews. Quantitative data were analyzed using descriptive statistics and Two-Way ANOVA, while qualitative data were analyzed thematically. The results showed that the DOCAR learning model significantly improved students' mathematical creative thinking compared with conventional instruction. Students with high self-efficacy also achieved better creative thinking performance. Qualitative findings confirmed that the DOCAR learning phases promoted active knowledge construction, collaboration, reflection, and confidence. The novelty of this study lies in integrating cognitive and affective perspectives through a Concurrent Embedded Mixed Methods approach, providing theoretical and practical contributions to student-centered mathematics learning.

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Corresponding Author:
Alfina Damayanti
Mathematics Education Study Program, Muhammadiyah University of Surabaya, Indonesia
**Email Correspondence:* alfinaadam02@gmail.com

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1. Introduction

The rapid advancement of science and technology has transformed the educational landscape, requiring learning processes to become increasingly innovative, student-centered, and responsive to the competencies needed in the twenty-first century. Mathematics education is expected not only to develop students' conceptual understanding but also to cultivate higher-order thinking skills, including creativity, critical thinking, collaboration, and communication (Shoffa et al., 2022). Among these competencies, mathematical creative thinking has received increasing attention because it enables students to generate multiple solution strategies, construct original ideas, and solve mathematical problems from different perspectives (Mulyaningsih & Ratu, 2018). Therefore, fostering students' mathematical creative thinking has become one of the primary goals of contemporary mathematics education.

Mathematical creative thinking refers to the ability to produce original, flexible, and meaningful mathematical ideas when solving problems. It involves exploring alternative solution strategies, establishing new mathematical relationships, and generating innovative approaches beyond routine procedures (Andiyana et al., 2018). Johnson defines creative thinking as a habit of mind that encourages imagination, intuition, and openness to new possibilities (Umar & Abdullah, 2020). Likewise, Silver identifies three essential indicators of mathematical creative thinking: fluency, flexibility, and novelty, which collectively represent students' capacity to generate multiple, diverse, and original mathematical solutions (Mulyaningsih & Ratu, 2018). Consequently, strengthening students' creative thinking has become an important objective for improving mathematics learning quality.

Previous studies have shown that cognitive ability alone is insufficient to develop mathematical creativity. Students' affective characteristics, particularly self-efficacy, play a significant role in determining how they approach mathematical tasks, persist in solving problems, and overcome learning difficulties (Hari et al., 2018). Self-efficacy refers to an individual's belief in his or her capability to organize and execute actions required to accomplish specific tasks (Nurani et al., 2021). According to Bandura, self-efficacy consists of three dimensions: magnitude (level), strength, and generality, all of which influence students' motivation, perseverance, and academic achievement (Imaroh et al., 2021). Students with high self-efficacy tend to be more confident in exploring alternative solutions, taking intellectual risks, and persisting when encountering complex mathematical problems, whereas students with low self-efficacy often experience anxiety, hesitate to express ideas, and avoid challenging tasks (Hendriana & Kadarisma, 2019). These findings indicate that self-efficacy is an important psychological factor supporting the development of mathematical creative thinking.

Despite its importance, previous research indicates that students' mathematical creative thinking and self-efficacy remain relatively low in many junior high schools (Badjeber & Purwaningrum, 2018; Jumroh et al., 2018). This condition was also identified through preliminary observations conducted at SMP Muhammadiyah 15 Surabaya. The observations revealed that many Grade VII students experienced difficulties in independently constructing mathematical concepts and solving problems systematically. Classroom interactions were predominantly teachercentered, limiting students' opportunities to explore different solution strategies and communicate mathematical ideas. Moreover, many students lacked confidence in expressing opinions, asking questions, and solving challenging mathematical problems, indicating relatively low levels of self-efficacy. These classroom conditions hinder the development of students' mathematical creative thinking and ultimately affect their learning achievement.

One important factor influencing students' creative thinking is the learning model implemented by teachers. An appropriate learning model can create meaningful learning experiences that actively engage students in constructing knowledge, collaborating with peers, and reflecting on their learning processes. One instructional model designed to facilitate these processes is the DOCAR (Do, Observation, Construction, Association, Reflection) learning model (Shoffa, 2022). The DOCAR model consists of five interconnected learning phases. During the Do phase, students identify contextual mathematical problems. In the Observation phase, students examine available information and analyze the characteristics of the problem. The Construction phase encourages students to construct solution strategies independently. During the Association phase, students collaborate, discuss ideas, compare different solution methods, and justify their reasoning. Finally, in the Reflection phase, students evaluate and communicate their learning outcomes. These learning activities are designed to encourage active participation, collaborative knowledge construction, problem solving, and reflective thinking, all of which are expected to improve students' higher-order thinking skills, including mathematical creative thinking.

Several previous studies have demonstrated the effectiveness of innovative learning models in improving mathematical thinking skills. Likewise, previous research on the DOCAR learning model has primarily focused on its effectiveness in enhancing students' critical thinking and problem-solving abilities (Shoffa et al., 2022). However, empirical evidence regarding the effectiveness of the DOCAR learning model in improving mathematical creative thinking, particularly when viewed from the perspective of students' self-efficacy, remains limited. Existing studies generally investigate creative thinking or self-efficacy separately, while few have examined how both variables interact within the implementation of the DOCAR learning model. Consequently, there is still limited understanding of whether differences in students' self-efficacy influence the effectiveness of the DOCAR model in developing mathematical creative thinking.

To address this research gap, the present study investigates the implementation of the DOCAR learning model in improving students' mathematical creative thinking by considering different levels of self-efficacy. Specifically, this study aims to: (1) examine the effect of the DOCAR learning model on students' mathematical creative thinking ability; (2) analyze differences in mathematical creative thinking among students with high, medium, and low self-efficacy; and (3) explore how students' self-efficacy influences the development of creative thinking during mathematics learning using the DOCAR model. The novelty of this study lies in integrating cognitive and affective perspectives by examining the effectiveness of the DOCAR learning model through the interaction between mathematical creative thinking and students' self-efficacy. The findings are expected to contribute both theoretically to mathematics education research and practically to the development of innovative mathematics learning models that support students' higher-order thinking skills.

2. Method

This study employed a mixed methods approach using a Concurrent Embedded Design, in which quantitative and qualitative data were collected during the same phase of the research but served different purposes (Creswell & Plano Clark, 2018). The quantitative component constituted the primary method (QUAN) because the study primarily aimed to examine the effectiveness of the DOCAR learning model on students' mathematical creative thinking ability across different levels of self-efficacy. Meanwhile, the qualitative component functioned as a supportive method (qual) to provide an in-depth explanation of students' creative thinking processes and to enrich the interpretation of the quantitative findings.

The quantitative phase adopted a quasi-experimental nonequivalent control group design involving one experimental class and one control class. Students in the experimental class were taught using the DOCAR learning model, whereas students in the control class received conventional direct instruction. Both groups completed a pretest before the intervention and a posttest after the learning process to measure improvements in mathematical creative thinking. In addition, all students completed a self-efficacy questionnaire to classify them into high, medium, and low self-efficacy groups.

The qualitative component was embedded within the experimental process. After the quantitative data had been analyzed, representative students from each self-efficacy category (high, medium, and low) were purposively selected for in-depth qualitative analysis. The qualitative data consisted of students' written solutions, classroom observations during the implementation of the DOCAR learning model, and semi-structured interviews exploring students' reasoning, problem-solving strategies, confidence, and learning experiences.

The integration of quantitative and qualitative data occurred at the interpretation stage through a process of connecting and merging. First, quantitative findings identified significant differences in mathematical creative thinking across learning models and self-efficacy categories. Subsequently, qualitative evidence was used to explain why these differences occurred by describing students' thinking processes, participation during learning, and confidence in solving mathematical problems. Thus, the qualitative findings served to strengthen, explain, and contextualize the statistical results rather than functioning as an independent analysis.

The population of this study consisted of all Grade VII students at SMP Muhammadiyah 15 Surabaya during the 2022/2023 academic year. Two classes were selected using purposive sampling: Class VII-B as the experimental group and Class VII-A as the control group, because both classes had comparable academic characteristics based on school recommendations and preliminary observations.

The research instruments included: (1) a mathematical creative thinking test consisting of two open-ended problems developed according to the indicators of fluency, flexibility, and novelty; (2) a self-efficacy questionnaire using a four-point Likert scale; (3) an observation sheet to document students' participation during learning; and (4) a semi-structured interview guide to explore students' creative thinking processes. All instruments were validated by mathematics education experts before implementation. The validity and reliability of the quantitative instruments were examined through pilot testing prior to the main study.

Quantitative data were analyzed using descriptive statistics and Two-Way Analysis of Variance (ANOVA) to determine the effects of the learning model and self-efficacy on mathematical creative thinking ability. Before hypothesis testing, assumptions of normality and homogeneity of variance were examined. Qualitative data were analyzed using thematic analysis involving data reduction, coding, categorization, and interpretation of emerging themes. The credibility of the qualitative findings was enhanced through data triangulation by comparing students' written work, classroom observations, and interview results. Finally, both datasets were integrated to produce comprehensive conclusions regarding the effectiveness of the DOCAR learning model in improving students' creative mathematical thinking from the perspective of self-efficacy.

3. Results and Discussion

a. Improvement of Students' Mathematical Creative Thinking

The quantitative findings indicate that students who learned through the DOCAR learning model demonstrated higher mathematical creative thinking ability than those who received conventional instruction. As presented in Table 1, the experimental and control classes showed relatively similar pretest mean scores (36.50 and 35.93, respectively), indicating comparable initial abilities. However, after the learning intervention, the experimental class achieved a substantially higher posttest mean score (71.70) than the control class (60.50). These findings indicate that the DOCAR learning model contributed positively to improving students' mathematical creative thinking ability.

Table 1 Data Recapitulation of pretest and posttest results

Information	Mean	Standard Deviation
Experimental Class		
Pretest	36,50	7,070
Posttest	71,70	10,148
Control Class		
Pretest	35,93	7,216
Posttest	60,50	9,719

The improvement can be explained by the characteristics of the DOCAR learning model, which actively involves students in identifying contextual problems, constructing mathematical ideas, discussing multiple solution strategies, and reflecting on their reasoning processes. These learning activities provide students with opportunities to demonstrate the three indicators of mathematical creative thinking fluency, flexibility, and novelty through meaningful mathematical experiences rather than routine procedural learning.

Classroom observations also revealed that students in the experimental class participated more actively during collaborative discussions. They were more willing to propose different solution strategies, ask questions, and justify their mathematical reasoning. In contrast, students in the control class tended to rely on teacher explanations and generally applied only one solution strategy when solving mathematical problems. These qualitative observations strengthen the quantitative findings by illustrating how the learning process facilitated the development of creative thinking.

b. Differences in Mathematical Creative Thinking Based on Students' Self-Efficacy

Students' mathematical creative thinking ability differed across the three self-efficacy categories. As shown in Table 2, students with high self-efficacy obtained the highest mean scores in both learning groups, followed by students with moderate and low self-efficacy. However, the experimental class consistently achieved higher scores than the control class within each self-efficacy category.

Table 2 Descriptive statistics of posttest results in terms of self-efficacy

Dependent Variable: Creative Thinking				
Learning Model	Self-efficacy	Mean	Std. Deviation	N
Experimental Class	Tall	86,57	2,440	7
	Keep	69,17	5,803	18
	Low	60,00	2,739	5
	Total	71,70	10,148	30
Control Class	Tall	75,80	3,347	5
	Keep	59,36	5,350	22
	Low	43,33	2,309	3
	Total	60,50	9,719	30
Total	Tall	82,08	6,171	12
	Keep	63,78	7,381	40
	Low	53,75	8,956	8
	Total	66,10	11,355	60

These findings suggest that self-efficacy plays an important role in students' mathematical creative thinking. Students who possessed higher confidence in their mathematical abilities demonstrated greater persistence, explored multiple solution strategies, and showed stronger willingness to communicate their ideas during classroom discussions.

The embedded qualitative findings provide further explanation for these differences. Students categorized as having high self-efficacy confidently presented their ideas, evaluated alternative solutions, and actively participated in group discussions. Students with moderate self-efficacy generally solved problems correctly but tended to rely on familiar procedures before attempting alternative approaches. Meanwhile, students with low self-efficacy frequently hesitated to express their opinions, waited for teacher confirmation before continuing their work, and often stopped after obtaining a single solution. These behavioural differences indicate that self-efficacy influences not only learning outcomes but also students' engagement in creative mathematical thinking.

c. Effects of the DOCAR Learning Model and Self-Efficacy

The hypothesis testing using Two-Way Analysis of Variance demonstrated statistically significant effects of both the learning model and students' self-efficacy on mathematical creative thinking ability. The analysis showed a significant main effect of the learning model ($p < .001$), indicating that students taught through the DOCAR learning model significantly outperformed those receiving conventional instruction. Likewise, self-efficacy also had a statistically significant effect ($p < .001$), indicating differences in mathematical creative thinking among students with high, moderate, and low self-efficacy.

These findings indicate that mathematical creative thinking is influenced by both instructional factors and psychological factors. Effective learning models provide opportunities for students to develop creative ideas, whereas self-efficacy determines students' confidence, persistence, and willingness to explore various mathematical solutions. Therefore, improving students' mathematical creativity requires instructional strategies that simultaneously strengthen cognitive and affective aspects of learning.

d. Integration of Quantitative and Qualitative Findings

Following the Concurrent Embedded Mixed Methods design, qualitative findings were integrated with quantitative results to explain how and why the DOCAR learning model influenced students' mathematical creative thinking.

The quantitative analysis demonstrated that the experimental class achieved significantly higher creative thinking scores than the control class. These statistical findings were supported by classroom observations showing that students experienced richer mathematical interactions during each phase of the DOCAR learning model.

During the Do phase, students identified contextual mathematical problems and began generating initial ideas. The Observation phase encouraged them to examine problem characteristics carefully before determining solution strategies. In the Construction phase, students independently developed mathematical solutions and justified their reasoning. The Association phase promoted collaborative discussion in which students compared different ideas, evaluated alternative solutions, and refined their mathematical arguments. Finally, the Reflection phase encouraged students to evaluate both their solutions and learning experiences, strengthening their metacognitive awareness.

Students with high self-efficacy were generally able to maximize every learning phase by confidently generating multiple solution strategies and communicating their reasoning. Students with moderate self-efficacy benefited from collaborative discussions that increased their confidence to explore new ideas. Meanwhile, students with low self-efficacy showed gradual improvement after receiving support from peers and teachers during the Association and Reflection phases. These integrated findings demonstrate that the effectiveness of the DOCAR learning model depends not only on its instructional design but also on students' psychological readiness to participate actively in mathematical learning.

e. Discussion

The findings of this study confirm that the DOCAR learning model effectively improves students' mathematical creative thinking ability because each learning phase facilitates higher-order thinking processes. The sequential learning activities encourage students to construct mathematical knowledge independently, compare multiple solution strategies, communicate their reasoning, and reflect on their learning experiences. Such learning characteristics are consistent with constructivist learning theory, which emphasizes active knowledge construction through meaningful interaction and reflection.

The findings also demonstrate that students' self-efficacy significantly influences the development of mathematical creative thinking. Students with stronger self-belief were more willing to take intellectual risks, generate alternative solutions, and persist when encountering unfamiliar mathematical problems. Conversely, students with lower self-efficacy tended to avoid challenging tasks and depended more heavily on teacher guidance. These results reinforce Bandura's theory that self-efficacy influences individuals' motivation, persistence, and performance in solving complex problems.

Furthermore, the present findings extend previous studies reporting the effectiveness of the DOCAR learning model in improving critical thinking and problem-solving abilities (Shoffa et al., 2022). Unlike previous research, the present study demonstrates that the effectiveness of the DOCAR model is also associated with differences in students' self-efficacy, suggesting that affective characteristics should be considered when implementing innovative mathematics learning models. Therefore, integrating cognitive learning strategies with psychological support may produce greater improvements in students' mathematical creativity.

The results also have practical implications for mathematics teachers. Learning activities should not merely emphasize procedural knowledge but should provide opportunities for students to explore multiple solution strategies, communicate mathematical ideas, collaborate with peers, and reflect on their reasoning processes. At the same time, teachers should create learning environments that strengthen students' confidence and encourage them to participate actively during mathematics learning. Such instructional practices are expected to foster both mathematical creative thinking and positive learning dispositions.

4. Conclusions

This study investigated the effectiveness of the DOCAR learning model in improving students' mathematical creative thinking ability by considering differences in students' self-efficacy. The quantitative findings demonstrated that students who learned through the DOCAR learning model achieved significantly higher mathematical creative thinking scores than those who received conventional instruction. Furthermore, students with high self-efficacy consistently outperformed students with moderate and low self-efficacy, indicating that self-efficacy is an important psychological factor influencing students' creative mathematical performance.

The embedded qualitative findings further explained these statistical results by showing that the five learning phases of the DOCAR model encouraged students to actively construct mathematical knowledge, discuss multiple solution strategies, justify their reasoning, and reflect on their learning experiences. Students with high self-efficacy demonstrated greater confidence in exploring alternative mathematical solutions, whereas students with lower self-efficacy required more collaborative support and teacher guidance to engage in creative thinking. These findings confirm that the effectiveness of the DOCAR learning model is influenced not only by instructional design but also by students' affective characteristics.

Theoretically, this study contributes to mathematics education literature by providing empirical evidence that mathematical creative thinking is developed through the interaction between innovative instructional models and students' self-efficacy. The integration of quantitative and qualitative findings offers a more comprehensive understanding of how cognitive and affective factors jointly influence students' creative mathematical performance. This study also extends previous research on the DOCAR learning model by demonstrating its effectiveness in fostering mathematical creative thinking across different levels of self-efficacy.

Practically, the findings suggest that mathematics teachers should implement student-centered learning environments that encourage collaboration, problem solving, reflection, and active participation while simultaneously strengthening students' confidence in learning mathematics. Such instructional practices are expected to improve both students' mathematical creativity and their willingness to engage in challenging mathematical tasks.

This study has several limitations. The research was conducted in only one junior high school with a relatively limited sample size, and the intervention was implemented over a relatively short period. Therefore, caution should be exercised when generalizing the findings to broader educational contexts.

Future research is recommended to investigate the long-term effectiveness of the DOCAR learning model across different educational levels, mathematical topics, and learning environments. Further studies may also incorporate additional affective variables, such as mathematical resilience, motivation, engagement, or metacognitive awareness, to develop a more comprehensive understanding of factors influencing students' mathematical creative thinking. Moreover, future research could employ longitudinal or explanatory sequential mixed methods designs to provide deeper insights into the development of students' creative thinking over time.

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Author Contributions

All authors contributed substantially to this study. Contributions included the conceptualization and design of the research, development of the research methodology, data collection, instrument validation, formal data analysis, interpretation of the findings, manuscript preparation, critical revision of the manuscript, and final proofreading. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work, ensuring the accuracy and integrity of the research.

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