THE OPEN-ENDED APPROACH WITH EFFECTIVE QUESTIONS STRATEGY: CAN IT ENHANCE STUDENTS' MATHEMATICAL CREATIVE THINKING SKILLS?

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Abstract

This study aims to describe the improvement of seventh-grade students' mathematical creative thinking ability through the implementation of an Open-Ended approach integrated with the Effective Questions strategy. The research specifically investigates four key indicators of creative thinking: fluency, flexibility, originality, and elaboration. A quasi-experimental method was employed using a pretest-posttest control group design. The sample was selected through purposive sampling, involving one experimental class and one control class, each consisting of 32 students. The data collection techniques included a mathematical creative thinking test and structured interviews. The results were analyzed using descriptive statistics to examine the average improvement and performance distribution across students, and inferential statistics using a one-sample t-test and normalized gain (N-gain) to assess the effectiveness of the intervention on each indicator. The findings demonstrate that the integration of the Open-Ended approach with the Effective Questions strategy has a significant positive impact on students' mathematical creative thinking skills. Specifically, the fluency and elaboration indicators showed high-level improvement with N-gain scores of 0.91 and 0.81, respectively. Meanwhile, the flexibility and originality indicators experienced moderate improvement, with N-gain scores of 0.61 and 0.38.

Keywords: *Open-Ended; Effective Questions; Mathematical Creative Thinking Skill*

Abstrak

Penelitian ini bertujuan untuk mendeskripsikan peningkatan kemampuan berpikir kreatif matematis siswa kelas VII melalui penerapan pembelajaran dengan pendekatan *Open-Ended* yang dipadukan dengan strategi *Effective Questions*. Fokus utama penelitian ini adalah pada empat indikator berpikir kreatif, yaitu *fluency* (kelancaran), *flexibility* (keluwesan), *originality* (kebaruan), dan *elaboration* (keterperincian). Pendekatan penelitian yang digunakan adalah metode eksperimen semu (*quasi-experimental*) dengan desain *pretest-posttest control group design*. Pemilihan sampel dilakukan secara purposive, dengan melibatkan satu kelas sebagai kelompok eksperimen dan satu kelas lainnya sebagai kelompok kontrol, masing-masing terdiri dari 32 siswa. Instrumen yang digunakan dalam

pengumpulan data adalah tes kemampuan berpikir kreatif matematis dan pedoman wawancara terstruktur. Data dianalisis melalui pendekatan deskriptif untuk menggambarkan rata-rata peningkatan dan distribusi hasil belajar siswa, serta analisis statistik menggunakan uji *one-sample t-test* dan perhitungan *N-gain* untuk menilai efektivitas perlakuan terhadap masing-masing indikator. Hasil penelitian menunjukkan bahwa penerapan pendekatan *Open-Ended* yang dikombinasikan dengan strategi *Effective Questions* terbukti mampu meningkatkan kemampuan berpikir kreatif matematis siswa secara signifikan. Peningkatan tertinggi terjadi pada indikator *fluency* dan *elaboration* dalam kategori tinggi (0,91 dan 0,81), sedangkan peningkatan pada indikator *flexibility* dan *originality* tergolong dalam kategori sedang (0,61 dan 0,38).

Kata Kunci: *Open-Ended; Effective Questions; Berpikir Kreatif Matematis*

A. Introduction

The rapid advancement of the era, especially in the 5.0 industrial revolution, has brought the widespread use of Artificial Intelligence (AI) into nearly every aspect of life. AI is capable of solving problems and delivering information quickly and precisely. This challenges the younger generation to have higher-order thinking skills to remain competitive with intelligent machines, robots, and algorithms.

Based on *World Economic Forum 2025* report (Zahidi, 2025), one of the core competencies needed in 2025 and will continue to grow until 2030 is creative thingking, even this ability becomes a core skill in 2030 besides AI and big data. Creative thinking helps individuals solve problems or crises with out-of-the-box thinking (Beghetto, 2024).

Guilford (1973) identified four key indicators that define creative thinking skills: the skill to produce numerous ideas (*fluency*), adapt to different perspectives or approaches (*flexibility*), produce unique or novel concepts (*originality*), and develop ideas in detail (*elaboration*) when addressing problems. Thus, creative individuals can solve problems with innovative, varied solutions, so that they do not hang every problem on AI. Thus, this skill is one of the abilities that must be developed, especially through classroom learning

However, this ideal is not yet realized in Indonesia. Indonesian students struggle with problems requiring creative thinking, such as PISA and TIMSS questions. Indonesia's PISA and TIMSS results are far from the international average and are ranked low. Indonesia's mathematical scores from PISA and TIMSS are presented in Table 1.

Table 1. Performance of Indonesian in Mathematics According to TIMSS and PISA Assessments

TIMSS			PISA		
Year	Rank/Total Countries	Average / International Average	Year	Rank/Total Countries	Average / International Average
2011	38/42	386/500	2012	64/65	375/494
2015	44/49	397/500	2015	66/70	386/490
2019	-	-	2018	72/78	379/489
2023	-		2022	63/81	366/472

Source : (Mullis et al., 2012, 2016; OECD,

2014, 2016, 2019, 2023)

The findings from TIMSS and PISA align with the outcomes of the national assessment, which reported numeracy competency levels at 43.03% in 2023 and 65% in 2024, both categorized as moderate (Kemendikdasmen, 2023, 2024). These three sets of data highlight the necessity of enhancing the learning process to better foster creative thinking skills.

Among various instructional models, the open-ended approach stands out as a viable method that can be employed by teachers in mathematics classrooms. This approach was first developed in Japan in the 1970s as part of a research project involving Shimada, Toshio Sawada, Yoshiko Hashimoto, and Kenichi Shibuya. Its primary aim is to evaluate students' mathematical high order thinking skills, This is achieved by presenting them with open-ended problems, problems that can be solved using multiple strategies and may have more than one valid answer (J. P. Becker & Shimada, 1997)

Agustianingsih & Mahmudi (2019) outline five ways to design open-ended problems such as (1) modifying closed-ended questions found in textbooks; (2) working backward—thinking of the answer first, then formulating a question and strategy to reach that answer; (3) formulating questions aimed at evaluating "who is correct?", in order to explore students' reasoning and perspectives; (4) utilizing the "what if not...?" technique to revise existing questions in line with the problem-posing approach; and (5) constructing questions that highlight "what's wrong with this?" by presenting an incorrect answer and prompting students to analyze the error, explain the reasoning behind it, and offer the correct solution.

Problems presented through the open-ended approach designed not only to develop students' accuracy in problem solving, but also to foster creative thinking by enabling them to find multiple correct answers, apply various problem-solving strategies, and formulate alternative solutions that are novel, uncommon, or original.

In addition to instructional approaches, the learning process is closely tied to teacher–student interaction, particularly in the form of questioning activities. In fact, teachers use about 50% of their instructional time for questioning, with 60% being *recall* questions, 30% related to classroom management, and only 10% aimed at exploring students' thinking skills (Almeida, 2012; Crockett, 2022).

However, most of the questions posed by teachers still focus on classroom management issues such as lesson schedules, attendance, or other technical matters. Furthermore, research indicates that teachers frequently employ closed-ended questions, true/false questions, and questions that require reasoning that only involves low-level cognitive processes, specifically those aligned with the remembering (C1) and understanding (C2) levels of Bloom's taxonomy(Aizikovitsh-

Udi & Star, 2011; Aziza, 2018; Faizah et al., 2018). These types of questions can generally be answered by students using only recall or memorization, which means teacher questions do not always foster the enhancement of students' critical thinking skills.

Mahmud & Mohd Drus (2023) suggest that integrating teacher questioning during instructional activities can facilitate the advancement of students' reasoning and promote a deeper understanding of mathematical concepts. However, in order to achieve this, teachers must be creative and varied in designing and posing such questions to students. Thus, appropriate or effective questions can improve students' mathematical thinking abilities.

If teachers aim to improve students' creative thinking ability, they must pose questions that stimulate such thinking, such as high-level questions. According to Juliangkary & Pujilestari (2022) and Willbourne (2004), there are several ways to formulate effective questions, including: avoiding recall-type questions or those unrelated to learning objectives, refraining from answering their own questions, directing questions to multiple students, and using high-level prompts such as "why," "how," "from where," and "when." By asking purposeful and effective questions, teachers can foster students' creative thinking skills.

Building on the earlier discussion, the *Open-Ended* approach with the *Effective Questions* strategy has the potential to be effective in improving students' mathematical creative thinking skills. Nevertheless, it is still uncertain which among the four creative thinking skills indicators shows the most significant development. Consequently, the objective of this research is to explore the advancement of students' mathematical creative thinking by implementing the *Open-Ended* approach with the *Effective Questions* strategy, with specific attention to each individual indicator of creative thinking.

B. Research Method

This research adopts a *quasi-experimental* approach, with a pretest-posttest group design to evaluate the effects of the intervention. This study utilizes the existing class structure at the school where the research was conducted. Sampling was carried out using purposive sampling, by selecting two classes VII as research subjects. Specifically, VII A was selected as as the experimental group, whereas VII B selected as the control group, with each class comprising 32 students.

A test designed to measure students' creative thinking skills served as the primary instrument for data collection. The test has met the validity standards or has been declared valid by expert judgment. In addition, the research instrument has also met the reliability standard with a reliability coefficient of 0.607 obtained using the Cronbach's Alpha formula. Data were also collected through student interviews.

The research data obtained were analyzed descriptively and statistically. Descriptive analysis included calculating the average scores, the percentage student performance in mathematics creative thinking, and classifying levels of mathematics creative thinking skills. The categorization of students' mathematical creative thinking skills used in this study are presented in the following table

Table 2. The Classification of Mathematical Creative Thinking Skills

Score Range	Category
$x \geq 89$	Very High
$78 \leq x \leq 89$	High
$67 \leq x < 78$	Moderate
$x < 67$	Low

Statistical analysis was conducted using a *one sample t-test* with the decision criterion that the null hypothesis H_0 is rejected if $t_{calculated} > t_{table}$, where $t_{table} = 2{,}0395$. Furthermore, the data concerning each indicator of creative thinking ability was examined using the N-gain test. The categorization of N-gain used is as follows.

Table 3. *N-Gain* Categorization

N-Gain Score	Category
$g \geq 0{,}7$	High
$0{,}3 \leq g \leq 0{,}7$	Moderate
$g < 0{,}3$	Low

This study used indicators of creative thinking ability as proposed by Guilford (1973) and Piirto (2011). The descriptions of each indicator and sub-indicator related to mathematical creative thinking skills utilized in this research are presented in the following table.

Table 4. Indicators of Mathematical Creative Thinking Ability

Indicator	Sub-indicator
Fluency (Kelancaran)	1. Able to establish strategies to solve the problem quickly, completely, and accurately. 2. Able to provide more than one correct answer.
Flexibility (Keluwesan)	1. Able to understand the problem from various perspectives. 2. Able to use several different strategies in solving problems.
Originality (Keterbaruan)	1. Able to find and use problem-solving strategies that are uncommon, different from most students, as well as unique and novel.
Elaboration (Keterperincian)	1. Able to solve problems with a sequence of steps that are clear, detailed, structured and related to each other.

C. Research Results and Discussions

The analysis of the research findings reveals the distribution of students' mathematical creative thinking skills before and after the intervention, as depicted in the following image.

Figure 1. Distribution of Students' Mathematical Creative Thinking Skills in *Open-Ended* Approach with the *Effective Questions* Strategy

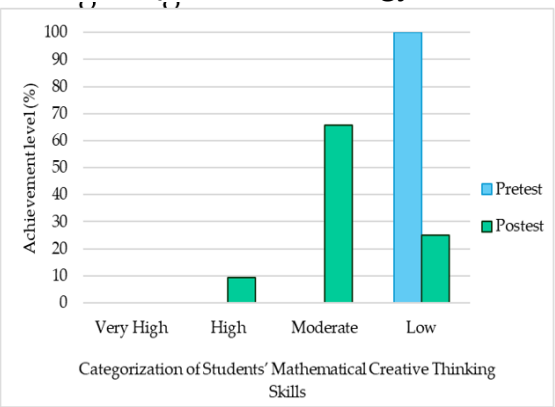


Figure 1 illustrates an improvement in students' creative thinking skills after following the instructional process. This indicates that the implementation of the open-ended approach combined with the effective questioning strategy has a beneficial impact on students' mathematical creative thinking.

Statistical evidence from a *one-sample t-test* supports this finding, as $t_{calculated} > t_{table}$ (2,061 > 2,0395). Therefore, it can be broadly inferred that the application of open-ended approach with the effective questions strategy can support the advancement of seventh graders' mathematical creative thinking skills.

This conclusion aligns with earlier studies conducted by Dewi & Juandi (2023) and Filbertha & Saragih (2024), who found that students who participated in learning with an open-ended approach experienced a more significant improvement in mathematical creative thinking skills compared to those taught through conventional method.

An open-ended instructional approach offers greater potential for students to develop their cognitive and thinking skills, because they are accustomed to exploring knowledge, discovering, recognizing, and solving problems using various strategies (Shimada, 2005). In learning with this approach, students are trained to deal with non-routine problems that have more than one solution strategy or answer. As a result, students become accustomed to and skilled in seeking diverse and original solutions.

In addition, the use of effective questioning strategies also known as *effective questions*, alongside an open-ended learning approach can act as an indirect form of teacher support for students. This enables students to discover and understand the concepts being studied and solve problems based on their own reasoning.

This indicates that integrating *effective questions* within *open-ended* approach has the potential to the enhancement of students' mathematical creative thinking skills. These findings aligned with Aziza (2018) study, which found that effective teacher questioning during the learning

process can stimulate students to think creatively.

Table 5. Frequency and Percentage of Students' Mathematical Creative Thinking Skill Performance in the Experimental Class

Score Range	Pretest		Posttest		Category
	f	%	*f*	%	
$x \geq 89$	0	0%	0	0%	Very High
$78 \leq x \leq 89$	0	0%	3	9,4%	High
$67 \leq x < 78$	0	0%	21	65,6%	Moderate
$x < 67$	32	100%	8	25%	Low
Mean Score	6,25		69,79		

Table 6. Frequency and Percentage of Students' Mathematical Creative Thinking Skill Performance in the Control Class

Score Range	Pretest		Posttest		Category
	f	%	*f*	%	
$x \geq 89$	0	0%	0	0%	Very High
$78 \leq x \leq 89$	0	0%	3	9,4%	High
$67 \leq x < 78$	0	0%	6	18,7%	Moderate
$x < 67$	32	100%	23	71,9%	Low
Mean Score	6,08		62,33		

Based on the data in Table 6 and Table 5, both the open-ended approach combined with the effective questions strategy and conventional teaching methods are capable of improving students' mathematical creative thinking skills. However, the students who received instruction through the open-ended approach combined with an effective questions strategy demonstrated more significant improvement compared to those in the class that received instruction with a conventional method. This is reflected in the average score increases: 63.54 for the experimental group versus 56.25 for the control group.

Furthermore, the percentage of students with low mathematical creative thinking skill was noticeably smaller in the experimental class (only 25% of the total students), while the control class had more than half of its students falling into this category. These findings demonstrate that the integration of open-ended approach with effective questions proves to be more beneficial in fostering students' creative thinking in mathematics compared to traditional/conventional instructional techniques.

To gain deeper insights, an additional analysis was performed on the creative thingking skills test results of the students from the experimental class. This aimed to determine which specific indicators of mathematical creative thinking showed high, moderate, or low levels of improvement. The analysis utilized the *N-Gain* method. The analysis outcomes can be observed in Table 7.

Table 7. Analysis of Students' Creative Thinking Performance through the Implementation of an Open-Ended Approach with and Effective Questions

Indicator	*N-Gain*	Category
Fluency	0,91	High
Flexibility	0,61	Moderate
Originality	0,38	Moderate
Elaboration	0,81	High

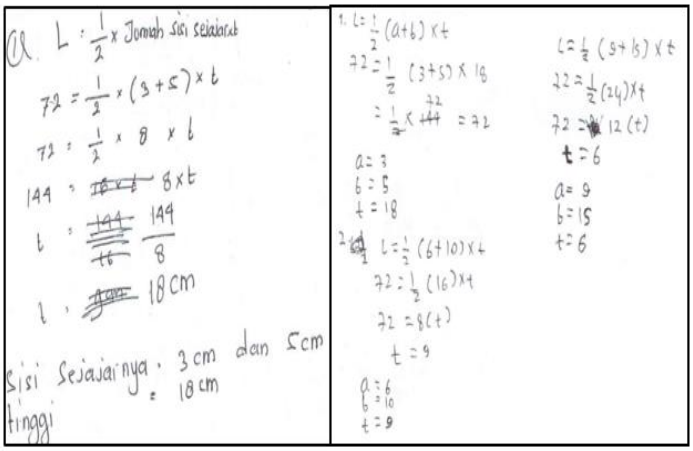
Based on Table 6, the implementation of open-ended learning using the effective questions strategy can enhance the *fluency* (kelancaran) indicator of creative thinking skills, with the level of improvement categorized as high. In this learning approach, students are encouraged to generate various possible answers or solutions to the given problems.

This type of learning shifts students' perceptions, making them aware that a single mathematical problem does not always have just one solution or one correct answer. When one student successfully solves a problem using a correct strategy, other students still have the opportunity to propose different but equally correct solutions. This creates a learning atmosphere that encourages students to actively develop their cognitive abilities, enabling them to independently explore and generate diverse solutions.

In *open-ended* learning, all student responses, whether expected or unexpected are discussed collectively. This can foster students' confidence in their own abilities, reinforcing the belief that they are capable of finding alternative correct answers. Consequently, during the learning process, students will be motivated, trained, and accustomed to utilizing all of their knowledge to find more than one correct solution.

For example, when students are asked to determine the lengths of the sides of a trapezoid with an area of 72 cm², students with high fluency are able to provide various possible combinations of side lengths that satisfy the given area. Examples of student responses reflecting both low and high fluency can be seen in Figure 2.

Figure 2. Comparison of Student Responses with Low and High *Fluency*



Low *Fluency* High *Fluency*

The second indicator of creative thinking skills that can be enhance through open-ended approach with the *effective questions* strategy is elaboration. In this learning, students are not only trained to find more than one correct answer but also to express their thinking processes through questions such as, "Why is this the answer?", "What if it isn't...?", or "Is there another way to solve this?". These types of questions encourage students to use their reasoning skills to connect previously learned concepts in order to solve problems. As a result, students become accustomed to constructing problem-solving processes that are clear, logical, and structured.

Referring to Table 6, the application of the open-ended approach combined with the effective questioning strategy also contributes to enhancements in the indicators of flexibility and originality, although the improvements still fall within the moderate category. One reason these two indicators only showed moderate improvement is that students tended to rely too heavily on formulas and previously given examples when solving problems, which limited the variety of problem-solving strategies they used.

Another reason for the less thanoptimal improvement in the *flexibility* indicator is that students were not yet able to understand problems from different perspectives. Students who do not attempt to comprehend problems from alternative viewpoints, such as by forming mental images of the problems and representing them in tables, graphs, or diagrams will struggle to solve the problem and will also find it difficult to come up with alternative solutions (Sternberg & Sternberg, 2012)

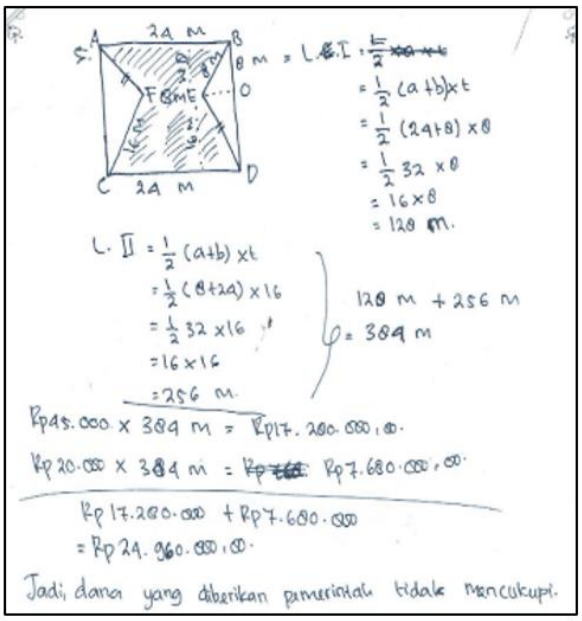
Based on the interview results, students' inability to understand problems from different perspectives is caused by their lack of self-confidence in comprehending and solving problems without assistance from others. Throughout the learning activities, students can understand and solve problems through discussions with peers and through guided questions provided by the teacher. However, when students are asked to solve problems independently, they struggle to offer alternative solutions that differ from the ones previously given.

The inability to understand problems from multiple perspectives can impact the types of alternative solutions provided by students. The solutions they offer tend not to be new, unique, uncommon, or different from those provided by other students. As a result, the creative thinking indicator of originality shows the lowest improvement compared to other indicators.

Although in open-ended learning using the effective questions strategy, students are trained to generate as many correct solutions as possible, they still struggle to produce solutions that meet the originality indicator. This difficulty is due to students only being able to provide solutions similar to those previously given and focusing primarily on the application of formulas.

Based on interviews, several students stated that they were unable to provide solutions that differed from the examples previously given or solved. The students were only able to use commonly used or general solution alternatives, those that had been applied before or previously provided by the teacher. An example of the students' lack of optimality in problem solving, viewed from the indicator of *originality*, can be seen in Figure 3.

Figure 3. Example of Problem Solving with Low Originality



According to Figure 3, when students were asked to calculate the area of the shaded region, most of them focused solely on solving the problem by using the shaded region itself. This situation arose because the students had not yet cultivated the ability to generate problem-solving strategies that diverged significantly from those applied in familiar examples or previously examples. In fact, students could approach the problem in Figure 3 from a different perspective, such as by utilizing the unshaded region to resolve the problem.

The results of this research align with those reported by Arifani et al. (2015) and Istiqomah et al. (2018) who stated that fluency and elaboration are indicators of creative thinking skills that are more easily improved through open-ended learning. Meanwhile, the indicators of flexibility and originality are more difficult to enhance, or the percentage of students who showed improvement in these two indicators was lower than two previous indicators.

However, an improvement in a single indicator does not necessarily reflect the overall proficiency in students' mathematical creative thinking skills. For instance, students who demonstrate a high level of fluency cannot yet be considered to have a high performance of mathematical creative thinking skills.

A student is considered to possess a very high mathematical creative thinking skills when they can demonstrate all four indicators concurrently. According to Arifani et al. (2015), students who exhibit only a strong level of fluency are still classified as having a low creative thinking skills.

Therefore, in implementation of open-ended approach with the *effective questions* strategy, teachers need to foster habits and build students' confidence to understand and solve problems from different perspectives. This will help improve all indicators comprehensively and lead to students developing a very high level of creative thinking skills.

D. Conclusion

Derived from the presented data and discussion, it can be inferred that implementation of open-ended approach with effective questions strategy can advance the mathematical creative thinking skills of seventh-grade students. Specifically, (1) *fluency* (kelancaran) and *elaboration* (kerincian) showed

improvement in the high category, while (2) *flexibility* (keluwesan) and *originality* (kebaruan) showed improvement in the moderate category.

These results indicate that *flexibility* and *originality* remain the more challenging indicators of creative thinking to cultivate through the learning process. Therefore, teachers should make extra efforts by implementing innovative teaching strategies, particularly those that train students to understand problems from different perspectives, enabling them to construct solutions that are novel, unique, and unconventional.

Implication

Based on the conclusions drawn from this study, the author offers the following suggestions:

a. For Mathematics Teachers

The open-ended approach combined with the effective questions strategy can serve as an alternative instructional method that mathematics teachers may implement to enhance students' creative thinking skills. Throughout the learning process, teachers should not only present open-ended problems but also provide guidance and ample opportunities for students to express their opinions, ask questions, and articulate their thought processes in solving problems. Every student's response should be appreciated and given constructive feedback.

b. Further Research

Future researchers may further analyze various methods, models, and learning approaches that can contribute more positively to the advancement of each indicator of mathematical creative thinking skills, so that the improvement all four indicators can reach a high category.

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