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Improving Creative Thinking Skills through Open-ended Problems in Mathematics Education in terms of Adversity Quotient (Types of Climbers and Campers)

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ABSTRACT

Creative thinking is one of the abilities that students must have. This research aims to explore creative thinking skills in solving open-ended problems in grade 7 students at a junior high school in Surakarta. This research uses a qualitative method. The instruments used are questionnaires, questions, and interviews. The test instrument uses one open-ended question on algebra material. The sampling method was carried out by purposive sampling where the subject was selected based on the results of the Adversity Response Profile (ARP) questionnaire score. The research subjects were 7th-grade students at one of Surakarta's private junior high schools who had studied algebraic form operations. Data were collected through tests and interviews with 4 research subjects. The data validity used was method triangulation. The results of the study show that all subjects can go through all stages of the creative thinking process although there are differences in each stage. In the preparation stage, climbers-type students do not need a long time to understand the problem. Unlike the campers, they take time to understand the problem by reading it repeatedly. At the incubation stage, students pause to look for ideas for solving the problem. At the illumination stage, students have different ways of solving the problem. At the verification stage, climbers-type students recalculate the answers written to check their correctness. While campers type students only skim the answers they write. Climbers-type students do not give up easily and do not experience difficulties in solving problems, while campers-type students take longer to understand the problem and almost give up in solving the problem. Based on the findings obtained, teachers need to consider the different types of students' creative thinking in designing class activities in order to improve students' creative thinking abilities through classroom learning.

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A. INTRODUCTION

Creative thinking is required to generate new ideas or solve mathematical problems (Hadar & Tirosh, 2019). The ability to synthesize ideas, generate new ideas, evaluate effectiveness, and make decisions are examples of complex products that can be generated through creative thinking (Ferdiani et al., 2022). The usefulness of creative thinking extends beyond mathematics and applies to everyday life problem-solving as well (Gunawan et al., 2022). Creative thinking is the ability to discover new ideas or find solutions to problems (Suherman & Vidákovich, 2022). This definition is based on Guilford (1967) notion that creativity can be classified into eight components: flexibility, fluency, originality, analysis, reorganization, redefinition, synthesis, complexity, and elaboration. Efforts to measure creative thinking abilities in mathematics often involve asking students to generate multiple solutions to specific problems (Leikin, 2009). These solutions are then assessed to measure fluency and creativity using an originality index (Shaw et al., 2022).

The solution to mathematical problems requires creative thinking (Ferdiani et al., 2022). Problem-solving requires creativity and is closely related to creative thinking (Plucker et al., 2004; Setyana et al., 2019). Students should be able to combine concepts, techniques, procedures, and ideas previously learned in both mathematics and other fields in new ways to solve problems (Schoevers et al., 2020). Problem-solving is part of life skills that involve analysis, interpretation, prediction, evaluation, and reflection (Anderson, 2009). Problem-solving in the context of mathematics is students' ability to solve mathematical problems in various life contexts by involving their mathematical abilities (Feser et al., 2023). Problem-solving has been identified as a key component of mathematics teaching and learning worldwide (Tong et al., 2020). The ability to solve problems refers to a person's capacity to solve problems that arise in everyday life (Intaros et al., 2014). However, the reality is that student's ability to solve mathematical problems is still relatively low (Aisyah et al., 2021).

Open-ended problems are mathematical problems that have more than one approach and multiple correct answers. In the context of mathematics education, open-ended problems are non-routine problems that allow for multiple correct answers and various problem-solving strategies (Rizos & Gkrekas, 2023). A problem is said to be open-ended if the initial or final conditions are not precisely defined (Feser et al., 2023). It is recognized that open-ended problems can help students enhance their ability to think creatively in mathematics (Fatah et al., 2016; Ulinnuha et al., 2021). Unlike traditional classrooms that focus on closed problems, mathematics groups that engage in active mathematical thinking skills with open-ended problems are also effective in developing creative problem-solving abilities (Yuniarti et al., 2021).

Open-ended questions are an effective measurement tool that can assess students' creativity in both the outcomes and processes from elementary school to college (Rahayuningsih et al., 2021; Suherman & Vidákovich, 2022). Open-ended questions provide opportunities for students to provide different answers while being able to generalize, thus influencing students' creativity in generating new ideas(Bingölbali & Bingölbali, 2021). The use of open-ended questions in mathematics learning is effective in supporting creative thinking abilities and serves as a measurement tool for creative thinking abilities (Septiani et al., 2022). Each student has a different process of creative thinking, so teachers need to accompany and appreciate students' creativity in finding problem solutions (Ulinnuha et al., 2021).

When discussing students' mathematical creativity, teachers have a role in selecting mathematical tasks that students should solve (Levenson, 2013). Creativity in the classroom does not refer to absolute creativity but is relative (Supandi et al., 2021). Relative creativity considers the creativity associated with a specific group. The development of mathematical creativity is often seen as a recommendation and ultimate goal of education. Educational research efforts often aim to develop frameworks for evaluating creativity, especially through problem-posing and problem-solving (Supandi et al., 2021). To foster student creativity, the learning environment must be productive, open to inquiry and exploration, and consider students' cultural values (Palinussa, 2013). However, the current learning conditions in Indonesia do not provide sufficient opportunities for the development of student creativity and learning achievement (Ndiung et al., 2021).

Overall, considering the facts, issues, and needs mentioned above, creative thinking is deemed necessary to be applied in mathematics learning, including through the practice of solving open-ended problems and teacher guidance. Based on the explanations provided above, the objective of this research is to examine how students' creative thinking processes manifest in solving open-ended problems. The importance of the ability to think creatively as one of the fundamental abilities in mathematics, one of which helps students in solving mathematical problems. Open-ended problems are a form of mathematical problem that can be used to improve or assess students' creative thinking abilities (Muhaimin et al., 2024). Based on the urgency of this research, this research aims to explore how students' creative thinking processes are realized in solving open-ended problems.

B. METHODS

This study was conducted to address a research question concerning the process of creative thinking in solving open-ended algebra problems. Qualitative research was chosen as an alternative approach for this study. Qualitative research is an approach that explores and understands the individual or group meanings derived from social or human issues. The design used in this study was phenomenological. Phenomenological research is an investigative design that originates from philosophy and psychology, where researchers describe individuals' lived experiences of a phenomenon as described by the participants. The observed phenomenon in this study is the students' creative thinking process in solving open-ended problems.

Qualitative research is characterized as multi-paradigmatic, where researchers operate from diverse worldviews such as post-positivism, interpretivism, and critical orientations. This results in a highly varied field of investigation, thereby involving qualitative researchers in research projects (Leavy, 2014). As a consequence, researchers serve as the primary instrument and exercise complete control over the entire research process. Additionally, researchers utilize supportive instruments such as tests and interview guidelines to aid their investigation.

The test instrument was developed based on creative thinking indicators, including fluency, flexibility, and novelty. The process of making test instruments is by adapting indicators of creative thinking ability to the material used, namely algebra. From the process of creating the questions, one question was obtained which contained indicators of creative thinking ability in algebra material. After the test instrument was created, the researcher validated the instrument with an expert validator in the field. Instrument validation results show that the instrument can be used with revisions, and the results of the revision or final instrument along with the subject's answers are clearly presented in the results and discussion. The appropriateness of the test items with the indicators to be measured was evaluated by four validators, who confirmed the usability of the instrument. The interview guidelines, on the other hand, provided a reference for conducting in-depth interviews with the research subjects to validate the results of the students' work.

Data were collected through tests and interviews with 4 research subjects. The subjects were previously categorized into three groups based on the adversity response profile (ARP) score. The students were classified as climbers, campers, or quitters, based on their adversity quotient (AQ) levels. Climbers were students with scores between 135 and 200 on the ARP, while campers were students with scores between 60 and 134 (Stoltz, 2006). However, in this study, only two categories were identified: climbers and campers. This was due to the absence of student scores below 56, as indicated by the ARP questionnaire. Subjects in each category were selected using a purposive sampling technique. Two subjects were selected from the climbers category, and 2 subjects were chosen from the campers category. Detailed information about each selected subject is presented in Table 1.

Table 1. Selection of Research Subjects

Student Code	ARP Score	AQ Category
CL-1	178	Climbers
CL-2	142	Climbers
CM-1	134	Campers
CM-2	100	Campers

Before conducting the research, content validation of the items was carried out, including material, sentence construction, and language. The instrument validation was conducted by expert validators, consisting of three mathematics education professors and one mathematics teacher. To ensure the research is unbiased, data validity is essential. The data validity employed in this study utilizes the method of triangulation. The data analysis technique uses inductive techniques which include data collection, data reduction, data presentation, and drawing conclusions (Sutama, 2019). Data collection was carried out by giving tests and interviews to research subjects, tests in the form of open-ended problems were given to the four research subjects directly and after giving the test an in-depth interview was carried out as confirmation of the subject's test answers. After the data was obtained, the data was reduced by sorting the important and necessary data to be presented in this article. Data is presented based on indicators of creative thinking ability. After the data is presented, the data is then interpreted by analyzing it based on the responses shown by students during tests and interviews, then the data is discussed with theory and previous research.

C. RESULT AND DISCUSSION

The research findings and analysis of the collected data are presented below. The results of the study include a test on the student's creative thinking process in solving open-ended problems related to algebraic operations, as well as the conducted interviews. The questions were designed to measure the indicators of fluency, flexibility, and novelty exhibited by the subjects in their responses to open-ended questions that required them to find algebraic equations resulting in $4x^2$. Figure 1 depicts the utilized question.

The result of dividing the algebraic form A by B is $4x^2$.
Determine at least two possible algebraic forms for A and B.

Figure 1. Creative thinking question

1. Subject CL-1 with Climbers Type

In this problem, the students are expected to generate ideas. Subject CL-1 demonstrated the ability to solve the problem effectively.

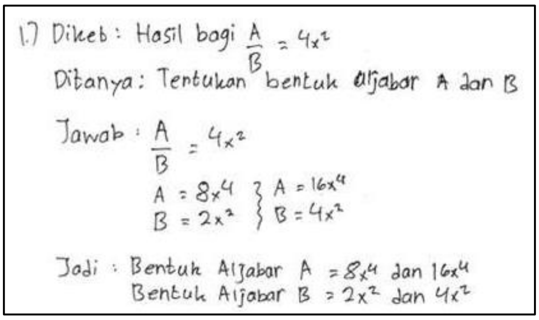

Figure 2. CL-1's work result

Based on Figure 2, it can be observed that the provided response adequately addresses the question posed in the problem. Subject CL-1, during the problem-solving process, demonstrated the ability to recall and apply the acquired knowledge. The subject quickly comprehended the problem, as evidenced by their prompt identification and inclusion of relevant information on the worksheet. According to the interview findings, subject CL-1 exhibited proficiency in overcoming challenges encountered while solving the problem.

During the preparation stage, subject CL-1 initially read the problem to gain an understanding of the information presented. This was evident during the interview, as the subject attentively examined the instructions and pertinent details provided within the problem statement. Subsequently, the subject swiftly grasped the problem, indicating prompt assimilation of its requirements. The incubation stage was manifested when subject CL-1 engaged in a period of contemplative reflection, discerning the gathered information and formulating viable strategies to tackle the problem. Notably, CL-1 acknowledged a momentary lapse in recalling the specific approach to algebraic division, necessitating an illumination stage characterized by a trial-and-error process until the correct solution was reached. Furthermore, the subject gradually recollected the principles of algebraic division within the context of the problem at hand. In the verification stage, CL-1 expressed confidence in successfully solving the problem without significant difficulties. The subject emphasized the importance of meticulous calculations for obtaining accurate results. Additionally, subject CL-1 diligently cross-checked the written response by carefully re-evaluating the problem and meticulously reviewing the solution presented in the worksheet from beginning to end. This process aligned with the findings of Nuha et al. (2018), which highlight the evaluative aspect of the verification stage in assessing the accuracy and validity of the solution method employed. Based on the comprehensive account provided by subject CL-1 regarding the distinct stages of the creative thinking process in problem-solving, as analyzed through the lens of Wallas' theoretical framework, these insightful observations can be succinctly summarized in Table 2.

Table 2. Creative Thinking Process of Subject CL-1 in Solving the Problem

No	Wallas' Stage		Problem-Solving Process of Subject CL-1
1.	Preparation	a.	Subject CL-1 carefully reads the given problem
		b.	Subject CL-1 sxhibits expressions of recalling the relevant material
2.	Incubation	a.	Subject CL-1 is observed in a brief period of silence, identifying information to determine problem-solving strategies
		b.	Subject CL-1 is also seen playing with a pen while formulating problem-solving strategies
		c.	Subject CL-1 makes rough notes, displaying expressions to recall the relevant material used in solving the given problem
3.	Illumination	a.	Subject CL-1 begins to generate ideas for solving the problem, occasionally expressing confusion in finding the final result
		b.	After attempting to find a solution for several minutes, subject CL-1 appears uncertain about the written answer
		c.	Subject CL-1 starts recalling the relevant material and becomes confident in the obtained answer
		d.	Towards the end of the work, subject CL-1 carefully copies the answer onto the worksheet
4.	Verification	a.	Subject CL-1 can write a conclusion based on the worked-out answer
		b.	Subject CL-1 is observed being meticulous in checking their answer

2. Subject CL-2 with Climbers Type

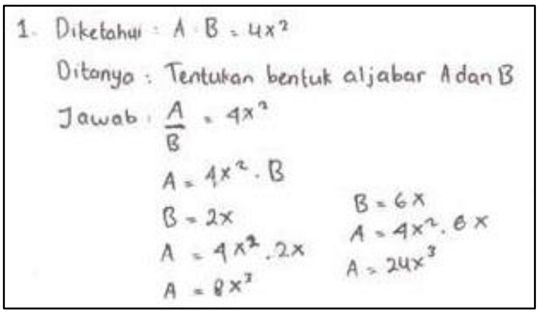

Figure 3. CL-2's work result

In line with subject CL-1, subject CL-2 exhibits proficient problem-solving skills in the aspect of fluency. Based on Figure 3, the subject demonstrates the capability to solve problems by initiating the process with a clear presentation of the given information, the question at hand, and the proposed solution methodology. Subject CL-2 requires a slightly longer duration to complete the problem. During the interview, the subject acknowledged a slight lapse in recalling the concepts related to algebraic operations. Nevertheless, subject CL-2 displays determination and perseverance in overcoming this challenge and successfully solving the problem at hand.

During the preparation stage, the student reads the problem carefully and attempts to describe what is being asked in the same language as the problem. They write down the information provided in the problem. However, the subject does not take a long time to understand the information in the problem. In the incubation stage, subject CL-2 engages in contemplation while rereading the problem and appears momentarily silent. Subject CL-2 is observed attempting to recall the concepts related to algebraic operations, and at this stage, the subject presents the strategies to be used in solving the problem. In the illumination stage, subject CL-2 begins to execute the previously planned strategy, which involves finding the equation for A and B by transforming the original division equation into a multiplication equation. Subject CL-2 transforms the equation $\frac{A}{B} = 4x^2$ into $A = 4x^2 \times B$. The subject proceeds with their plan by substituting the variable B with $2x$ and $6x$, as the question does not specify any constraints. During the verification stage, subject CL-2 re-reads the answer they have written from beginning to end and identifies errors in the computation. This indicates that subject CL-2 performs a final check on their written answer. Additionally, subject CL-2 admits to encountering slight difficulty in formulating problem-solving strategies due to a minor lapse in recalling the concept of algebraic operations. Table 3 depicts the creative thinking process of subject CL-2 in solving the problem based on Wallas' stages.

Table 3. Creative Thinking Process of Subject CL-2 in Solving the Problem

No	Wallas' Stage	Problem-Solving Process of Subject CL-2
1.	Preparation	a. Subject CL-2 reads the given problem carefully b. Subject CL-2 displays expressions of recalling previously taught material
2.	Incubation	a. Subject CL-2 reads the problem repeatedly b. Subject CL-2 exhibits a momentary silence and displays expressions of recalling the material on algebraic operations
3.	Illumination	a. Subject CL-2 begins to generate ideas for solving the problem. The process starts with trial and error, leading to recalling the concepts of algebraic operations b. Subject CL-2 appears uncertain about the written answer, as indicated by their reflective expressions
4.	Verification	a. Subject CL-2 recalculates to ensure the accuracy of the answer they have worked on b. Subject CL-2 admits experiencing difficulty in formulating strategies, stating a minor lapse in recalling the concepts of algebraic operations

3. Subject CM-1 with Campers Type

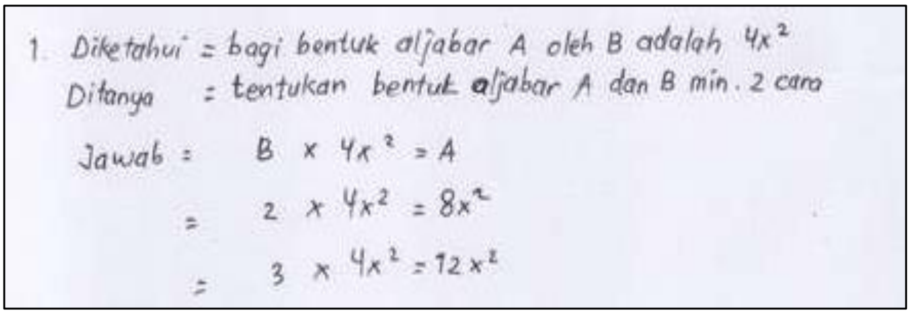

Figure 4. CM-1's work result

Based on Figure 4, subject CM-1 successfully solved the problem. During the preparation phase, CM-1 read the problem twice, first aloud and then quietly. An interview conducted with CM-1 revealed that CM-1 was able to explain the given information, including the known and requested information about the problem. In the incubation phase, CM-1 attempted to solve the problem by initially dividing it, but there was some hesitation, and CM-1 sought confirmation on the chosen method. Subsequently, CM-1 silently pondered the problem, contemplating a problem-solving strategy while glancing at the wall for potential solution ideas. CM-1 solved the problem by transforming the equation into $B \times 4x^2 = A$, thus moving the B equation to the right side and employing multiplication as the operation. CM-1 felt confident when making this equation transformation and proceeded to articulate its strategy during the illumination phase. It is evident from the working sheet that CM-1 wrote down $2 \times 4x^2 = 8x^2$ and $3 \times 4x^2 = 12x^2$. CM-1 mentioned that they chose arbitrary numbers for B since the problem did not provide any specific constraints. In the verification phase, CM-1 carefully reviewed their answers by rereading what they had written. When asked about the accuracy of their answers, CM-1 responded with a nod, indicating their confidence in the solutions. CM-1 reported no difficulties in solving the problem and considered it to be a straightforward task, despite initially reading the problem multiple times. This can be concluded in Table 5 based on the explanation provided by subject CM-1 regarding the stages of the creative thinking process in problem-solving, as observed from Wallas' stages. This can be concluded in Table 4 based on the explanation provided by subject CM-1 regarding the stages of the creative thinking process in problem-solving, as observed from Wallas' stages.

Table 4. Creative Thinking Process of Subject CM-1 in Solving the Problem

No	Wallas' Stage	Problem-Solving Process of Subject CM-1
1.	Preparation	a. Subject CM-1 reads the given problem aloud b. Subject CM-1 tries to understand the information in the problem
2.	Incubation	a. Subject CM-1 is observed to be momentarily silent, identifying information to determine problem-solving strategies b. Subject CM-1 reads the problem silently, then gazes at the wall while contemplating problem-solving strategies
3.	Illumination	a. Subject CM-1 starts to generate ideas for solving the problem by transforming the equation into multiplication form b. Subject CM-1 begins to recall the relevant material and becomes confident in the obtained answer
4.	Verification	a. Subject CM-1 reviews their work and expresses confidence in the written answer b. Subject CM-1 admits no difficulty and considers the problem to be straightforward

4. Subject CM-2 with Campers Type

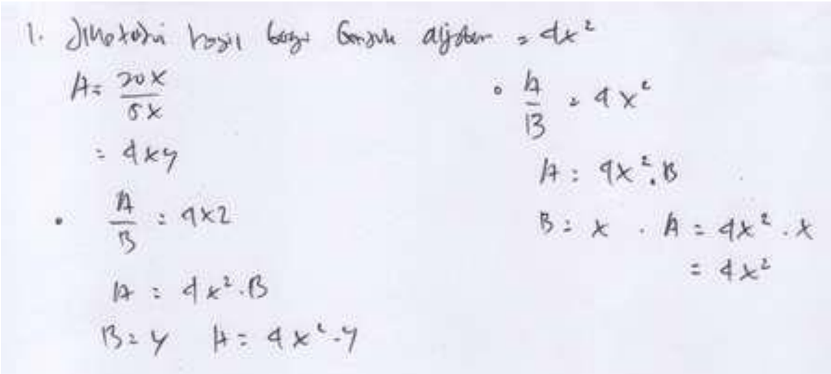

Figure 5. CM-2’s work result

According to Figure 5, subject CM-2 successfully solved the problem. They started by writing down the given information from the problem, although they initially did not specify the question being asked. However, during the interview, subject CM-2 clarified the question. In the preparation stage, subject CM-2 thoroughly read the problem and quickly grasped the information without encountering any significant challenges. They had no difficulties understanding the information provided in the problem. During the incubation stage, the subject appeared momentarily silent, engaging in the process of formulating problem-solving ideas. In the search for ideas, subject CM-2 conducted experiments by manipulating the equation given in the problem. They transformed the equation $\frac{A}{B} = 4x^2$ into $A = 4x^2 \times B$ as the initial step in solving the problem. Subsequently, subject CM-2 implemented their strategy in the illumination stage by substituting the variable B with y and x, resulting in the equations A as $4x^2y$ and $4x^3$, obtained from $4x^2 \times y$ and $4x^2 \times x$. As for the verification stage, during the interview, the subject mentioned reviewing the answers they had written on their worksheet. Subject CM-2 felt confident that the calculations on the answer sheet were correct, as they recalculated the answers and aligned them with the concept of algebraic operations, ensuring there were no computational errors. This finding is consistent with the research conducted by Akhsani et al. (2022), which suggests that students often state conclusions without being aware of the accuracy of their obtained results. Subject CM-2 admitted facing some difficulties in solving this problem, but they persisted and did not easily give up. This can be concluded in Table 5 based on subject CM-2's presentation of the stages of the creative thinking process in problem-solving according to Wallas' stages.

Table 5. Creative Thinking Process of Subject CM-2 in Solving the Problem

No	Wallas' Stage	Problem-Solving Process of Subject CM-2
1.	Preparation	a. Subject CM-2 reads the given problem b. Subject CM-2 tries to comprehend the information in the problem
2.	Incubation	a. Subject CM-2 is observed to pause momentarily, identifying information to determine problem-solving strategies b. Subject CM-2 attempts to formulate problem-solving strategies through trial and error while recalling the rules of algebraic operations
3.	Illumination	a. Subject CM-2 begins to discover ideas for solving the problem, starting with trial and error until finding a solution idea b. Subject CM-2 starts to recall the relevant material and becomes confident in the obtained answer
4.	Verification	a. Subject CM-2 performs recalculations to ensure the accuracy of the worked answers, although still exhibiting some doubts regarding the correctness of the written answers b. Subject CM-2 admitted that he had a little difficulty in solving this problem

The results of this study indicate that some findings are consistent and inconsistent with previous research. Climber-type subjects are able to comprehend the questions well and, in the incubation stage, they are able to formulate strategies and implement them in the illumination stage. This is in line with the findings of Chabibah et al. (2019) that students with climber-type characteristics can understand problems, formulate strategies, and implement them. This research supports Stoltz (2006) that climbers have the determination to progress and strive to reach higher levels. This corresponds to climber students who struggle and attempt to find problem-solving solutions. In the study, camper-type subjects were able to solve problems despite difficulties in understanding the information in the questions. This is consistent with the research by Aisyah et al. (2021), which states that camper-type students still have difficulties in comprehending questions and asking questions to the researchers. Students with camper-type characteristics show little initiative and enthusiasm in solving problems, but they still make an effort to work on the questions by finding the best solutions (Chabibah et al., 2019; Stoltz, 2006).

D. CONCLUSION AND SUGGESTIONS

Based on the research findings and discussions, it can be concluded that the creative thinking process of climbers-type students involves reading the problem, comprehending the information, and documenting it during the preparation phase. During the incubation phase, these students tend to pause, carefully observe the information, and speculate potential problem-solving strategies. In the illumination phase, climbers-type students apply their planned strategies by connecting known information and performing calculations. In the verification phase, they review their answers and have confidence in the solutions they have provided. In contrast, campers-type students approach the preparation phase by reading the problem multiple times to grasp the information. During the incubation phase, they tend to reflect and pause longer, carefully observing the problem, and requiring more time compared to climbers-type students. In the illumination phase, campers-type students implement the strategies they have designed during the incubation phase. In the verification phase, they verify the accuracy of their answers by rereading their written responses.

This research is limited to the selection of climbers-type and campers-type, future research can expand the exploratory study to add or conduct similar research but with other types of creative thinking subjects. Then this research is also limited to the selection of material on open-ended problems (algebra), therefore further research can expand to the selection of other mathematical materials. Based on the research conclusions, teachers need to consider the different types of students' creative thinking in designing class activities in order to improve students' creative thinking abilities through classroom learning. In addition, teaching materials must be designed to support both types of students. For example, materials that allow students to stop and reflect as well as materials that encourage careful observation and strategic planning.

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