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The Profile of Creative Thinking Process: Prospective Mathematics Teachers

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ABSTRACT

Purpose The creative thinking process is one of the important components of creativity. The profile of the creative thinking process of prospective mathematics teachers based on the level of creativity is explained in this study.

Methodology –The applied research method was qualitative with an exploratory approach. The research involved 35 prospective mathematics teachers in the Multivariable Calculus course. The data collection techniques were creative thinking tests and interviews. Data analysis uses data reduction techniques, presentation, and conclusion drawn.

Findings –The stages of the creative thinking process include preparation, incubation, estimation, illumination, and verification stages. The study results show that the profile of the creative thinking process of students in the creative and creative category can find unique ideas, and their application is carried out in detail. Each stage of creative thinking is fulfilled clearly. Especially for the estimation stage, it is a new finding in the creative thinking process. The estimation stage makes a real contribution to the birth of creativity. The term to describe the estimation stage is "trial and error."

Significance –The findings show that the estimation stage, or "trial and error," helps accelerate the acquisition of creative ideas. This stage is a strategic solution to increase creativity. However, using teaching materials or student worksheets must still be increased to implement the estimation stage in the problem-solving flow.

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INTRODUCTION

Creativity is one of the 21st-century skills that students must acquire (Ariyana et al., 2018; Gafour &

Gafour, 2020). Creativity is an individual ability to generate new theories or knowledge (Walia, 2019). Creativity is closely related to a new product but inseparable from a process (Al-Ababneh, 2020; Green et al., 2024). In learning mathematics, creativity is important to solve problems (Supandi et al., 2021). Creativity is essential to problem-solving (Abdulla et al., 2020). Creative students can apply unusual solutions or algorithms to solve problems (Tan et al., 2019). One step in solving mathematical problems is a trial calculation or experiment, called trial error. The experimental stage helps students think creatively (Logman et al., 2015; Sitorus, 2016).

Creativity comprises four parts: creative product, creative people, creative environment, and creative thinking process (MacKinnon, 2017; Wadaani, 2015). A creative environment is a social environment that supports productivity and creative thinking. Creative products are the obtained results from the creative process. The creative thinking process refers to finding new ideas (Lubart et al., 2015). Botella et al. (2016) group the creative thinking process into macro and micro creative thinking processes. At the macro level, the creative thinking process presents the stages of creativity.

In contrast, the micro-level explains the underlying rules of a creative process, such as divergent and convergent thinking. Research on creative thinking processes is essential because the thinking process facilitates students to realize creative ideas (Daly et al., 2016). Students can learn some patterns for producing creative products. This process applies to all disciplines, including mathematical problem-solving. From the data on the research field, many students were unaware of creative thinking processes (Daly et al., 2016). This research provides a pedagogical approach to developing students' creative thinking processes, namely skill building, domain knowledge, significant projects, open-ended assignments, creation in novel contexts, building repertoire, student critiques, instructor feedback, cross-disciplinary interaction, practitioner models, theories of the creative process, self-reflection, risk and failure experiences, and perspective taking.

The book "*The Art of Thought*" discusses four creative thinking processes: preparation, incubation, illumination, and verification. The preparation stage includes problem identification and information collection. (Van Hooijdonk et al. ,2020) explain the importance of finding facts and problems as the beginning of new ideas. The incubation stage means the student is temporarily free from the problem. However, the brain works to find inspiration—the illumination stage deals with insight, a process to gather all knowledge and create initial creative ideas. The illumination stage also connects the knowledge and the given problem. (Sitorus, 2016) explains that connecting concepts facilitates creative solutions. The verification stage refers to a stage of reexamining and refining creative ideas.

Several factors that influence creativity include cognition (Kandler et al., 2016; Kozlowski et al., 2019), personality (Puryear et al., 2017), and the environment (Rubenstein et al., 2018). Cognitive aspects are related to thinking activity levels, such as remembering, reasoning, thinking critically, and thinking creatively. Silvia (2015) explains that intelligence links intelligence and creativity. Many researchers have promoted research on creativity levels. Nuha et al. (2018) grouped the level of creativity into five categories based on the creative thinking indicators. They were very creative (level 4), creative (level 3), reasonably creative (level 2), less creative (level 1), and not creative (level 0). Because students have different backgrounds and characteristics of abilities, students' creative thinking will also have different levels. The level of creativity describes how much cognitive level or thinking students have in producing creative ideas.

The problem-solving process still experiences several obstacles, especially in the creative solution ideas used. For mathematical problems with a high level of difficulty or requiring high-level thinking skills, there must be simple stages that can come up with different ideas. This also applies to mathematics content learned in higher education. In answering problems, students still use monotonous solutions and do not want to try other, more systematic ideas. This condition requires different breakthroughs to help students find creative solutions. Scientific studies related to the stages of creative thinking are important to help students with difficulties finding creative ideas, especially for students with low and limited cognitive abilities.

The observations during the learning process show that the creative thinking process of students in determining creative ideas is carried out through several stages, one of which is simple and fast calculation. Written tests conducted by several students show the same thing. Creative ideas that arise cannot be directly found; students first look at the problem in depth. Before the idea is found, a simple and quick counting activity is carried out. The simple definition in question is the use of notation or symbols that do not follow the rules in mathematics. The formula used is also not well written. However, the results obtained are correct and appropriate to the problem and carried out quickly. This condition becomes unique if applied to other similar content in mathematics. This stage becomes more important if it can be applied to complex and contextual problems so that exploration of students' creative thinking stages is important to be carried out in the learning process. This stage will also have a positive impact on problem-solving using creative ideas. Students will learn the correct way to solve other math problems.

This condition needs a comprehensive and scientific solution. For students to find creative ideas and apply them appropriately, they must have systematic and detailed stages of thinking at each step, especially for students with low cognitive abilities. One of them is the existence of the trial and error stage. This stage can be an essential part of the creative thinking process. Before finding an idea, a test is carried out to be more confident that the idea suits the problem (Logman et al., 2015). Trial and error is part of the preparation of ideas. In problem-solving, problem orientation and idea discovery are inseparable from simple and quick trial-and-error activities (trial and error stage) (Cartwright, 2020; Ott et al., 2018). Thus, it is necessary to strengthen in-depth problem orientation activities and experiments to discover creative ideas and make it easier for students to solve mathematical problems.

Research on the theory of creative thinking processes has been carried out before. Research by Sadler-Smith (2015) modified the stages of the creative thinking process of the Wallas model. The research found different stages of creative thinking and their characteristics. The stages of the thinking process that are carried out to obtain creative ideas include preparation, incubation, intimation, illumination, and verification. The approach used in the study is between consciousness and unconscious. Sitorus (2016) researches the creative thinking process with a grounded theory approach in Realistic Mathematic Education (RME) learning, including orientation, preparation, incubation, illumination, and verification stages. However, this research is limited to contextual mathematical problems. Similarly, the research of Maharani et al. (2017) describes the process of creative thinking on contextual problems in geometric materials. Unlike the previous one, this research focuses on the stages of a more solutive creative thinking process with a grounded theory approach specifically for abstract problems. Sawyer (2021) researched the stages of the creative thinking process for problems related to art and design.

The stages of the creative thinking process consist of iteration, ambiguity, exploration, emergence, failure and dead ends, deliberate, conscious reflection, and the importance of constraints. These eight stages refer to pedagogic activities and practical experiences in the classroom. Research Saeed and Ramdane (2022) apply the creative problem-solving (CPS) model to increase students' creativity in high school. It has been proven that significant improvements have been made to the CPS model. The CPS model also realizes academic achievement, conceptual ability, and higher-level thinking. In addition, research was conducted by Gunawan et al. (2023), which defined the activity of creative thinking in solving open-ended problems. The creative thinking process includes identification, exploration, construction, and evaluation. The term used in the context of the research is divergent thinking.

The difference between the research conducted and the previous one lies in content, context, and competence. The content of this research is related to the stages of the thought process, which consists of preparation, incubation, estimation, illumination, and verification. The differentiating stage of creative thinking is the estimation stage. Students with limited cognition will have difficulty finding ideas, so there needs to be a stage to bridge the process of discovering different ideas. The context aspect applied is related to conceptual and complex materials in higher education, especially mathematics. The competency aspect involves a high level of cognitive thinking. Exploration and problem analysis activities are required before answering the problem. This research is important because it provides a solution that effectively finds creative ideas. The condition of students in the transition period from high school to college certainly requires a strong cognitive aspect. However, not all students have a good cognitive level. Before creativity appears, it is necessary to present problems with easy-to-understand and simple information, making it easier to find creative solutions (Cartwright, 2020; Rahayu et al., 2023).

The cognitive level of each student is different. Strong initial knowledge will affect a person's cognitive level, including finding creative ideas (Wijaya et al., 2023). If you have more knowledge and experience in solving problems, it will be easier to achieve creativity. Studying research results and theories about the creative process can help creativity. In this case, knowledge of the stages of obtaining creative ideas is essential. Therefore, the research question is, " How is the creative thinking process of prospective mathematics teachers in solving problems based on the level of creativity?". It is hoped that the results of this study will contribute findings that can be used for further research and help students find creative solutions.

METHODOLOGY

Research Design

This study uses a qualitative approach with a descriptive-explorative design. The research explores conditions in depth using written and oral data about students' creative thinking processes. This study aims to describe the creative thinking process of prospective mathematics teachers based on their level of creativity. An exploratory approach can be used to learn in-depth and provide an understanding of the characteristics of each stage of creative thinking, especially when finding creative solutions.

Participants and Data Collection

The researchers gathered the data from Mathematics Education students who took the Multivariable Calculus course. In this research, the participants consisted of 35 people. Based on the test results, students are grouped based on their level of creativity, namely very creative, creative, enough creative, less creative, and not creative. Researchers took two subjects from the category of very creative and creative with a purposive sampling technique (Sukestiyarno, 2020). The selection of very creative subjects is based on the completeness of the achievement of all creative thinking indicators, starting from fluency, flexibility, originality, and elaboration. Both levels have different and unique answers and ways of completion. This condition will make it easier to investigate the creative thinking process systematically. According to the research of Nuha et al. (2018), each level of creativity has criteria based on indicators of creative thinking ability. Table 1 describes the characteristics of each level of creativity. The researcher labeled the subject to facilitate the data analysis stage.

Table 1. Characteristics of Creativity Levels (N = 35)

Level	Characteristics
Very Creative	Write down several different and correct answers, use different ways of solving, and write down different or unique solutions.
Creative	Write down several different and unique answers, or several others, and use several different ways of solving.
Enough Creative	Using several different and unique ways of solving, producing unique answers, or using several different ways of solving.
Less Creative	Write down several different variations of the answer.
Not Creative	No answer.

The researchers collected the data from creative thinking tests, interviews, classroom observation, and students' written work. The researchers designed the questions based on the creative thinking indicators about the materials of limit and continuity. The questions consisted of one item. Table 2 describes the creative thinking test questions, answer rubrics, and criteria for originality and uniqueness. This explanation provides information on the criteria for a solution idea to be said to be creative/unique. Table 2 helps identify each student's answer for the categorization of creativity level. Identify the level of creativity using aspects of fluency, flexibility, originality, and elaboration.

Table 2. Creative Thinking Test Rubric

Question	Aspect	Answers	Criteria
Given the function $f: D \to R$ and $D \subseteq R^2$, with R is the set of all real numbers. The definition of a continuous function *f* is built from the limit definition of the function *f*. a. Given more than one different f function with a limit value at a point, but each f function is not continuous at that point? b. Give more than one way of solving to show that function *f* has a limit value (can take one of the functions created in (1) or create a new one, then prove it in detail)?	Fluency Flexibility	**(1.a.)** Students create two functions with a limit value that is not continuous. For example, a rational function is combined with a root function. Example: **Function 1:** $f(x,y) = \frac{x^2 - y^2}{x - y}$ The function f has a limit value of 0 for $(x,y) \to (0,0)$ but is not continuous in (0,0) because the value of *f* (0,0) is undefined. **Function 2:** $f(x,y) = \frac{xy}{\sqrt{x}}$ The function f has a limit value of 0 for $(x,y) \to (0,0)$ but is not continuous in (0,0) because the value *of f* (0.0) is not defined. **(1.b.)** Students use two different methods/algorithms to show the limit value, and the result is the correct value. For example, students use substitution and factoring. By creating a function $f(x,y) = \frac{x^2 - y^2}{x - y}$. It will be shown that *f* has a limit value in (1,0). Example: **Substitution Rules:** $f(1,0) = \frac{1^2 - 0^2}{1 - 0} = \frac{1}{1} = 1$ **Factoring Rules:** $\lim_{(x,y)\to(1,0)} \frac{x^2 - y^2}{x - y} = \lim_{(x,y)\to(1,0)} \frac{(x-y).(x+y)}{x-y} = \lim_{(x,y)\to(1,0)} (x+y) = 1 + 0 = 1$.	Originality and unique Originality and unique

The researchers also used expert judgment to validate the test items for the questions. An expert with an educational background in the field of creativity has received many research funds inside and outside Indonesia and has published research results on creativity internationally. After that, the researcher conducted a limited test. The instrument assessment process is carried out using a validation sheet and is carried out offline and online. After being evaluated by experts, the instrument developed to measure the creative thinking process is considered valid and reliable for research. Then, the researchers checked the learners' works and grouped them based on their creativity level. The researcher assessed students' work using a four-scale rubric. Then, the researchers interviewed the three primary subjects. Information regarding the background of participants is shown in Table 3.

Table 3. Personal Information of Participants (N = 35)

Criteria	Number	Percentage
Gender		
Male	5	14
Female	30	86
Age		
< 18 years	5	14.3
18-20 years	28	80
>20 years	2	5.7
Religion		
Islam	35	100
Christian	0	0
Buddhism	0	0
Grade Point Average (GPA)		
Less	5	14.3
Enough	5	14.3
Good	12	34.3
Very Good	13	37.1
Middle school educational background		
State	28	80
Private	7	20

The profile of the research subjects is illustrated in detail in Table 3. The number of men is more than the number of women. There is still a spread between the number of men and women. The average age of the subjects was 18-20 years. This condition showed that the subjects were already in an adult state and were easy to communicate with and think at a higher level. Regarding grade point average (GPA), most subjects have a suitable category of cognitive ability, making it easier to explain the problem-solving process. The subject's educational background comes from a public school, which, of course, has adequate facilities and infrastructure. This can form a student mindset with a good learning environment. These conditions support exploring the analysis of students' creative thinking processes in solving mathematical problems.

Analyzing of Data

The researcher analyzed the data using a qualitative approach consisting of three stages: data reduction, data presentation, and drawing a conclusion. Data reduction includes summarizing the data obtained, selecting important data, and organizing the data. All students' creative thinking test answers are corrected and scored. Furthermore, students are grouped into creativity levels based on score assessment. The researcher reduced the data based on the research topic, namely the creative thinking process. The results of the written test and interviews from the selected subjects were then presented with data on the stages of creative thinking based on the level of creativity in the form of pictures, descriptions, and tables. Each figure and table is explained according to the research topic being discussed. After that, the researcher concluded from the data and explained the findings obtained from the students' answers and interviews. The research findings obtained are also associated with the results of relevant previous studies. The conclusion given is in accordance with the purpose of the research, namely the characteristic profile of students' creative thinking process based on the level of creativity in solving mathematical problems. The creative thinking process used in the research consists of preparation, incubation, estimation (trial and error), illumination, and verification. The indicators of each stage are presented in Table 4.

Table 4. Indicators of Creative Thinking Processes

Stage	Indicators
Preparation	1. Write down known information 2. Remembering previously acquired knowledge related to information and problems
Incubation	1. Write down prior knowledge that has been previously acquired 2. Finding mathematical concepts related to the information asked and known
Estimation	Perform mathematical calculations quickly and or by trial and error
Illumination	1. Finding solution ideas 2. Apply ideas to problems 3. Write detailed answers
Verification	Recheck ideas

FINDINGS

The researchers designed the creative thinking test based on fluency, flexibility, originality, and elaboration. The fluency aspect shows the number of different and correct answers. Flexibility means the number of different and correct solutions/algorithms. Originality deals with generating unusual or unique ideas. The elaboration deals with students' ability to detail. Data analysis starts from the results of the student's creative thinking test. The answer sheet is used to classify students according to their level of creativity and find information about students' creative thinking processes in solving problems. The stages of each creative thinking process are obtained from the answer sheets and the results of student interviews. The researchers grouped the students based on the mathematical creative thinking skill test results in this research. The groups were creative, creative, enough creative, less creative, and not creative. Figure 1 shows the number of each level.

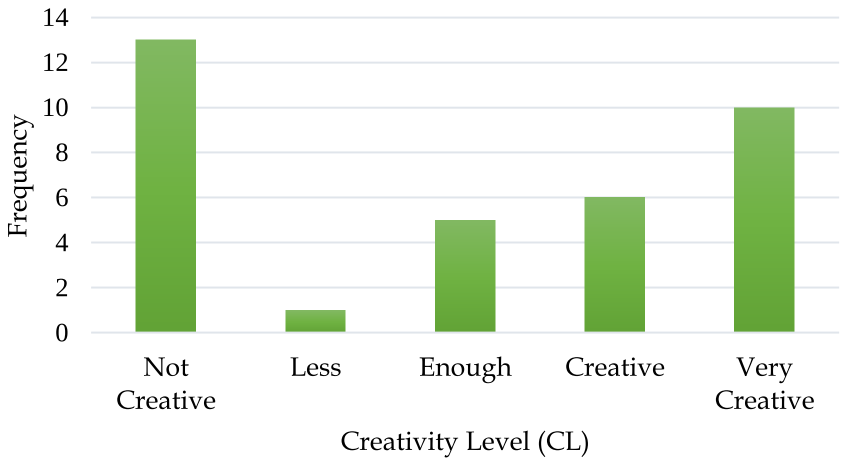

Figure 1. The Number of Students in Each Level of Creativity

The researcher took one subject from the creative and creative categories to explain the creative thinking process. Table 5 describes the score of each subject's creative thinking ability indicator on each question.

Table 5. Creative Thinking Skill Test Scores

No	Subjects	Indicators				Score	Levels
		Fluency	Flexibility	Originality	Elaboration		
1	Student 1 (S 1)	4	4	4	4	95	Very Creative
2	Student 2 (S 2)	4	4	4	3	80	Creative

Table 5 shows the score of S1 answers. The answer had new and correct ways of solving problems based on originality. From the result, S1 was in the very creative category. S2 wrote a new solution without a complete process. Thus, the researcher categorizes S2 in the creative group—an explanation of the creative thinking process based on the results of the three test subjects and in-depth interviews. Table 6 describes information on the results of identifying creative thinking processes based on the level of creativity.

Table 6. Results of Identification of Creative Thinking Processes

Stage	Levels	
	Very Creative	Creative
Preparation	Clear	Clear
Incubation	Clear	Clear
Estimation	Clear, quickly	Clear, quickly
Illumination	Detailed, unique	Detailed, unique
Verification	Clear	Clear

According to Table 6, students in the creative and creative category meet all stages of creative thinking clearly and thoroughly. Starting from the preparation, incubation, estimation, illumination, and verification stages. In the estimation stage, both subjects could perform simple calculations clearly and quickly. This is done to ensure that the idea to be used is the main problem. The illumination stage shows that the solution idea applied is unique or different from the previous one. This proves that the idea of the solution is creative.

Creative Thinking Process for Very Creative Students

Based on the results of the work of S1 subjects, Table 7 explains the identification of the stages of the creative thinking process, starting from preparation, incubation, estimation, illumination, and verification.

Table 7. S1 Work Result Analysis

Stage	Cognitive Activity	Analysis
Preparation	Write down the Initial information	1. Write down the definition of a real-value function 2. Write the limit definition of the function f as the value L for every x close to c
Incubation	Write down relevant prior knowledge	1. Considering the concept of factoring the limit of the function obtained earlier 2. Write down the factoring form $(a^2 - b^2, (x - y)$
Estimation	Perform simple and fast calculations	1. Using the direct substitution method 2. Using factoring methods 3. The results of both methods obtained the same results

Illumination	Applying ideas to problems	Fluency 1. Creating a function I: 2. $f(x,y) = \begin{cases} x^2 - y^2, (x,y) \neq (3,1) \\ 0, (x,y) = (3,1) \end{cases}$ 3. Creating a function II: $f(x,y) = \begin{cases} x^4y - x^3 + y, (x,y) \neq (1,3) \\ 0, (x,y) = (1,3) \end{cases}$ 4. Each function has a limit value 5. Function I and function II prove to be discontinuous 6. Both functions have a limit value but are not continuous Flexibility 1. Applying the substitution method 2. Apply factoring methods 3. With both methods, the results obtained are the same 4. Function 5. $f(x,y) = \begin{cases} \frac{x^3 - xy^2}{x+y}, (x,y) \neq (2,1) \\ 0, (x,y) = (2,1) \end{cases}$ has the same limit value in (x,y) close to (2,1) is 2
Verification	Checking	1. Double-check the idea used 2. Checking the entire process, starting from the symbols and steps

Based on Table 7, S1 subjects carry out activities ranging from writing down known information and preliminary knowledge previously obtained and relevant to the problem, conducting calculation experiments, implementing solution ideas on problems, and rechecking the work results. These cognitive activities describe systematic and detailed stages. The solution method was obtained from cognitive activity at the estimation stage by using two different completion methods and creating different functions where each function has the same limit value but is not continuous. Both questions on the aspects of fluency and flexibility can be answered precisely and clearly. This condition is in line with what has been conveyed by the S1 subject in the following interview.

> *First, I write down what information is known and pay attention to the problem. After remembering my previous experience, I calculate fast, ignore the writing of symbols, and am predictive. After that, I am sure I will write in detail and neatly. Next, I use the idea to solve the problem. In the fluency question section, I wrote two different functions of the same type, namely compound functions. This idea came about because I have seen teachers explain it in class, but I do not understand. I think that compound functions are a new idea, and I rarely use them. Then, in part of flexibility, I use two different methods of settlement: direct substitution and factoring. This idea was obtained from previous scribbles, and I used both methods while studying. Finally, I rechecked the completion steps, checked the writing of mathematical symbols, and corrected them. I usually use a few minutes to review the answers.* (Interview S1, 28 October 2024).

Creative Thinking Process for Creative Students

The researchers also found that S2 did the same thing. Table 8 describes the cognitive activities and analysis of the creative thinking process of S2 subjects at the stages of preparation, incubation, estimation, illumination, and verification, respectively.

Table 8. S2 Work Result Analysis

Stage	Cognitive Activity	Analysis
Preparation	Write down the Initial information	1. Write down the definition of a real-value function 2. Explain the main problem

Incubation	Write down relevant prior knowledge	1. Write down a compound function $f(x,y) = \begin{cases} 5x-2y-7, for\ (x,y) \neq (1,2) \\ 2, for\ (x,y) = (1,2) \end{cases}$ 2. Compound functions are composed of linear functions or one variable and constant functions
Estimation	Perform simple and fast calculations	1. Write a compound function $f(x,y) = \begin{cases} \frac{2x+y}{\sqrt{2x}}, for\ (x,y) \neq (0,2) \\ 3, for\ (x,y) = (0,2) \end{cases}$ 2. Determining the limit value of the f function by the substitution method 3. Proving the function f is not continuous
Illumination	Applying ideas to problems	Fluency 1. Creating a function I: 2. $f(x,y) = \begin{cases} 5x-2y-7, for\ (x,y) \neq (1,2) \\ 2, for\ (x,y) = (1,2) \end{cases}$ 3. Creating a function II: $f(x,y) = \begin{cases} \frac{4x+y-3}{\sqrt{4x}-\sqrt{y}}, for\ (x,y) \neq (1,9) \\ 2, for\ (x,y) = (1,9) \end{cases}$ 4. With the substitution method, each function has a limit value 5. Function I and function II prove to be discontinuous 6. Both functions have a limit value but are not continuous Flexibility 1. Applying the substitution method 2. Apply factoring methods 3. Applying the root form rationalization method 4. With both methods, the results obtained are the same 5. Function 6. $f(x,y) = \begin{cases} \frac{4x+y-3}{\sqrt{4x}-\sqrt{y}}, for\ (x,y) \neq (1,9) \\ 2, for\ (x,y) = (1,9) \end{cases}$ has the same limit value in (x,y) close to (1,9), which is -10
Verification	Checking	1. Checking the completion idea 2. Double-check the results of the work

The description of the creative thinking stages of S2 subjects is seen in Table 8. It is not much different from the creative thinking process carried out by S1 subjects. However, there are some differences made by S1. At the preparation stage, S1 subjects not only write down known information in the form of definitions of fundamental functions but are able to explain the information asked. This contrasts S2, which does not explain explicitly but defines function limits. In the incubation stage, S2 subjects try to recall their experience writing a compound function composed of linear and constant functions. When proving a discontinuous function with the substitution method, a quick calculation is done. This is relevant to the previous stage and what will be done. In the illumination section, in the fluency aspect, S2 writes two different functions and uses the method of rationalizing the denominator form in the flexibility section. Other functions that can be formed are a combination of rational, constant, and root functions. This indicates that the design of the selected function is different or creative. In the verification section, the same thing is also done by S1 subjects, namely checking the entire answer. This is in line with what was described by the S2 subject through an interview that explained the actual conditions for completing the math period. Here is the description of the interview.

> *"First, I wrote down the initial information because it made it easier to do the questions. By writing down what I know, I can quickly answer questions. I use that information to come up with solutions. I immediately thought of*

compound functions because, previously, I often encountered them in classroom learning; it was more accessible and suitable for limited/continuous material. I answered each of the fluency and flexibility questions carefully. At the same time, I looked at the graffiti that had been made earlier. After finishing all the questions, I double-checked my work. The final result, the mathematical symbols, and the number of questions answered. Once everything is done, I am sure the answer aligns with the main question" (Interview S2, 10 November 10 November, 2024).

DISCUSSION

The research results prove that students with a very creative and creative level show a thinking process in producing new ideas consisting of preparation, incubation, estimation, illumination, and verification stages. In the process of creativity, students in the category are creative, show each stage clearly and in detail, and find unique ideas. The preparation stage provides students with the first step in understanding the problem, writing down information, and relating previous knowledge to the main problem. At this stage, all research subjects understood the core of the problem and wrote the given information from the problem. Valentina et al. (2015) also found that subjects identified problems at the preparation stage by writing the given information to solve problems. The selected data can be processed into a basis for preparing the initial plan for completion. Obtaining information at the preparation stage helped find the correct solution (Purba et al., 2017). Level students are very creative and able to write down initial information and recall the knowledge that has been acquired. The incubation stage becomes very important because the inspiration process takes shape. The incubation stage positively contributes to developing creativity (Sriraman, 2017). The emerging ideas will be interconnected and arranged without any direct work on the problem.

Every research subject had a different way of achieving inspiration. The order of the process was irregular. The subjects also searched for the connections among concepts to get the correct solution. In line with the research, Sitorus (2016) explained that students with a very creative level recall information obtained before and then correlate it with the main problem. Students also imagine the relationship that might be gained from the two so that it can help the initial idea emerge. After finding inspiration for ideas, the subjects initiated the process of estimation. Students performed simple calculations at this stage to interpret and ensure the ideas obtained were based on the problem. The term used in this stage is also called "trial and error". Students do quick calculations and test the accuracy of the ideas to be used. Not paying attention to whether the symbols or mathematical notations are correct. Students only focus on doing quick calculations to predict that the ideas they get are by the problem. These results support several findings about the existence of "trial and error" activities carried out by students to obtain ideas quickly (Logman et al., 2015; Sitorus et al., 2019). The students' results at the creative level show the stages of the creative thinking process correctly, clearly, and in detail, and the ideas are unique. The results of this study support several findings that the characteristics of the creative thinking process for students with a very creative and creative level are carried out with a structuring approach starting from preparation, incubation, estimation (trial and error), illumination, and verification (Zubaidah et al., 2017).

These results also explain that the "trial and error" stage is the key to obtaining the initial idea. The calculation process is carried out quickly without paying attention to the correctness of using symbols or mathematical notations as a bridge for creative ideas. There needs to be experimentation, digging deeper into possible solutions, and testing conjectures before creative ideas are implemented (Logman et al., 2015). Thus, the estimation stage, or "trial and error," is the first step in obtaining creative ideas and findings that differ from previous creative thinking processes.

In particular, the results of the study have an impact on early students who are entering the transition from high school to the university level. Entry-level students who have just entered college need help to create creative solution ideas. The limited ability of students and the lack of abstraction process make it difficult for students to understand mathematical concepts. The results of this study provide technical assistance regarding simple steps to obtain creative ideas, especially in solving mathematical problems. Through the stages of preparation, incubation, estimation, illumination, and verification, it is easy for students to obtain ideas quickly and precisely. The stages represent problems in the form of symbols, notations, or formulas in the process of developing strategies or solutions illustrated in the estimation stage in the creative thinking process.

Strengthening problem representation and constructing strategies is an essential part of problem-solving, which is also inseparable from the creative thinking process (Cartwright, 2020; Ott et al., 2018; Rahayu et al., 2023). Students can systematically apply the stages of the creative thinking process to facilitate understanding concepts and creativity.

Furthermore, this study also provides several implications in the context of innovation in mathematics education learning and teacher competency development. First, students can be given contextual problems with many answers or ways of solving them to develop creativity. The term used is open-ended issues. Math problems are not only limited to routine problems and low-level thinking but are already complex problems that require high-level thinking (HOTS). The problem-solving structure is adjusted to the preparation, incubation, estimation, illumination, and verification level. This can be an innovation made by teachers to improve creative thinking. Students can dig into information extensively and in-depth to find solutions for the main problem. Through open-ended and contextual problems, students can increase information and knowledge and develop their creative thinking (Gunawan et al., 2022). Second, in the context of improving competence, from the results of this research, teachers can be given additional training and assistance related to innovative learning strategies that can develop students' creative thinking skills. Teachers are given knowledge about *mind mapping* strategies to explore information as a supporting component of the preparation and incubation stages of the creative thinking process. Strong knowledge can help students find creative ideas that vary at the illumination stage. Positive teaching, teacher motivation support to students, and good innovative teaching strategies can support student creativity (Aziz et al., 2025; Blalock et al., 2024). Thus, providing contextual problems with an open-ended nature that is adjusted to structuring creative thinking stages is important to build students' creative thinking in solving mathematical problems. In addition, a focus on positive teaching implications and innovative learning strategies must be developed to increase creativity in the classroom.

CONCLUSION

The results and discussion provide the following conclusions. The five stages of the creative thinking process were preparation, incubation, estimation, illumination, and verification. Cognitive indicators at the preparatory stage were - writing the given information; at the incubation stage - writing the obtained previous knowledge and imagining the relationship between the problem and the information in the preparation stage; at the estimation stage - performing simple calculations to interpret and ensure the idea correctness; in the illumination stage - applying ideas to solve problems and writing detailed answer; and in the verification stage - reexamining ideas starting from writing mathematical symbols, solving algorithms, and the number of answered questions. This research's novelty is the estimation stage, or the "trial and error" stage.

In addition, students with creative and creative categories of creativity levels have the same cognitive activity in several stages of the creative thinking process. The preparation and incubation stages can be informed regarding the initial knowledge and the content of the problem. The estimation or "trial and error" stage is carried out quickly, and several experiments are carried out until the initial idea appears. The illumination stage finds a unique idea and its application to the problem in good detail. In the verification stage, students are used to recheck the ideas used and the answers that have been written. The primary key lies in the estimation stage kn, which is known as "trial and error," so students can find creative ideas. The research also has implications for teacher learning innovations and competence in the classroom. Teachers can apply the theory of creative thinking and develop it in learning for increased creativity.

An experimental method can be applied to improve this research. First, experimental research was carried out in the control class, and experiments were related to improving creative thinking skills. The solution is to design student worksheets and case studies for contextual and open-ended problems. It can also be done by modifying the student's workflow based on the stages of the creative thinking process. Second, identifying external factors can affect students' creativity, such as self-efficacy, learning style, or learning independence. This design reaffirms that creativity is not only influenced by cognition but can also be influenced by affective factors.

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REFERENCES

Abdulla, A. M., Paek, S. H., Cramond, B., & Runco, M. A. (2020). Problem finding and creativity: A meta-analytic review. *Psychology of Aesthetics, Creativity, and the Arts*, *14*(1), 3–14. https://doi.org/10.1037/aca0000194

Al-Ababneh, M. (2020). The concept of creativity: Definitions and theories. *International Journal of Tourism & Hotel Business Management*, *2*(1), 245–249.

Ariyana, Y., Bestary, R., & Mohandas, R. (2018). *Buku pegangan pembelajaran berorientasi pada keterampilan berpikir tingkat tinggi*. Direktorat Jenderal Guru dan Tenaga Kependidikan Kementerian Pendidikan dan Kebudayaan Hak.

Aziz, R., Maimun, A., Hamid, A., Masturin, M., & Efiyanti, A. Y. (2025). An exploration of students' creativity through a mixed-methods study in the classroom. *Journal of Education and Learning (EduLearn)*, *19*(2), 650–657. https://doi.org/10.11591/edulearn.v19i2.21649

Blalock, S. M., Goble, P., & Mozier, K. (2024). Teacher professional development training: Utilizing child-centered play therapy skills in the classroom. *International Journal of Play Therapy*, *33*(1), 1–11. https://doi.org/10.1037/pla0000209

Botella, M., Nelson, J., & Zenasni, F. (2016). The macro and micro creative processes. *Creativity and Learning*, 33–46.

Cartwright, K. (2020). Analyzing students' communication and representation of mathematical fluency during group tasks. *The Journal of Mathematical Behavior*, *60*(4), 1–13. https://doi.org/10.1016/j.jmathb.2020.100821

Daly, S. R. A., Mosyjowski, E., & Seifert, C. M. (2016). Teaching Creative Process across Disciplines. *The Journal of Creative Behavior*, *53*(1), 5–17. https://doi.org/10.1002/jocb.158

Daly, S. R., Mosyjowski, E. A., Oprea, S. L., Huang-Saad, A., & Seifert, C. M. (2016). College students' views of creative process instruction across disciplines. *Thinking Skills and Creativity*, *22*(4), 1–13. https://doi.org/10.1016/j.tsc.2016.07.002

Gafour, O. W., & Gafour, W. A. (2020). Creative thinking skills–A review article. *Journal of Education and E-Learning*, *4*(1), 44–58.

Green, A. E., Beaty, R. E., Kenett, Y. N., & Kaufman, J. C. (2024). The Process Definition of Creativity. *Creativity Research Journal*, *36*(3), 544–572. https://doi.org/10.1080/10400419.2023.2254573

Gunawan, G., Kartono, K., Wardono, W., & Kharisudin, I. (2022). Analysis of Mathematical Creative Thinking Skill: In Terms of Self Confidence. *International Journal of Instruction*, *15*(4), 1011–1034. https://doi.org/10.29333/iji.2022.15454a

Gunawan, Kartono, Wardono, & Kharisudin, I. (2023). Divergent Thinking Process of Prospective Mathematics Teachers: A Case Study of an Open-Ended Problem. *Journal of Higher Education Theory and Practice*, *23*(16), 124-142. https://doi.org/10.33423/jhetp.v23i16.6469

Kandler, C., Riemann, R., Angleitner, A., Spinath, F. M., Borkenau, P., & Penke, L. (2016). The nature of creativity: The roles of genetic factors, personality traits, cognitive abilities, and environmental sources. *Journal of Personality and Social Psychology*, *111*(2), 230-249. https://doi.org/10.1037/pspp0000087

Kozlowski, J. S., Chamberlin, S. A., & Mann, E. (2019). Factors that influence mathematical creativity. *The Mathematics Enthusiast*, *16*(1), 505–540. https://doi.org/10.54870/1551-3440.1471

Logman, P. S. W. M., Kaper, W., & Ellermeijer, T. (2015). Evaluation of students' learning process reinventing the general law of energy conservation. *Eurasia Journal of Mathematics Science and Technology Education*, *11*(3), 479–504. https://doi.org/10.12973/eurasia.2015.1323a

Lubart, T. I., Mouchiroud, C., Tordjman, S., & Zenasni, F. (2015). *Psychologie de la Créativité (Deuxième Edition) [Psychology of Creativity]*. Armand Colin.

MacKinnon, D. W. (2017). IPAR's Contribution to the Conceptualization and Study of Creativity. In D. W. MacKinnon (Ed.), *Perspectives in Creativity* (pp. 60–89). Routledge. https://doi.org/10.4324/9781315126265-3

Maharani, H. R., Sukestiyarno, S., & Waluya, B. (2017). Creative Thinking Process Based on Wallas Model in Solving Mathematics Problem. *International Journal on Emerging Mathematics Education*, *1*(2), 177-184. https://doi.org/10.12928/ijeme.v1i2.5783

Nuha, M. 'Azmi, Waluya, S. B., & Junaedi, I. (2018). Mathematical Creative Process Wallas Model in Students Problem Posing with Lesson Study Approach. *International Journal of Instruction*, *11*(2), 527–538. https://doi.org/10.12973/iji.2018.11236a

Ott, N., Brünken, R., Vogel, M., & Malone, S. (2018). Multiple symbolic representations: The combination of formula and text supports problem-solving in the mathematical field of propositional logic. *Learning and Instruction*, *58*(6), 88–105. https://doi.org/10.1016/j.learninstruc.2018.04.010

Purba, E. P., Sinaga, B. M., & Surya, E. (2017). Analysis of the difficulties of the mathematical creative thinking process in applying a problem-based learning model. *Advances in Social Science, Education, and Humanities Research*, *104*(1), 265–268. https://doi.org/10.2991/aisteel-17.2017.55

Puryear, J. S., Kettler, T., & Rinn, A. N. (2017). Relationships of personality to differential conceptions of creativity: A systematic review. *Psychology of Aesthetics, Creativity, and the Arts*, *11*(2), 59–68. https://doi.org/10.1037/aca0000079

Rahayu, R., Kartono*, K., Dwijanto, D., & Agoestanto, A. (2023). Problem-Solving Process of Students with a Reflective Cognitive Style Based on the Action-Process-Object-Schema Theory. *European Journal of Educational Research*, *12*(1), 41–58. https://doi.org/10.12973/eu-jer.12.1.41

Rubenstein, L. D., Ridgley, L. M., Callan, G. L., Karami, S., & Ehlinger, J. (2018). How teachers perceive factors influencing creativity development: Applying a Social Cognitive Theory perspective. *Teaching and Teacher Education*, *70*(2), 100–110. https://doi.org/10.1016/j.tate.2017.11.012

Sadler-Smith, E. (2015). Wallas' four-stage model of the creative process: More than meets the eye? *Creativity Research Journal*, *27*(4), 342–352. https://doi.org/10.1080/10400419.2015.1087277

Saeed, B. A., & Ramdane, T. (2022). The effect of implementing a creative thinking model on developing creative thinking skills in high school students: A systematic review. *Review of Education*, *10*(3), 1-13. https://doi.org/10.1002/rev3.3379

Sawyer, R. K. (2021). The iterative and improvisational nature of the creative process. *Journal of Creativity*, *31*(1), 1–6. https://doi.org/10.1016/j.yjoc.2021.100002

Silvia, P. J. (2015). Intelligence and Creativity Are Pretty Similar, After All. *Educational Psychology Review*, *27*(4), 599–606. https://doi.org/10.1007/s10648-015-9299-1

Sitorus, J. (2016). Students' creative thinking process stages: Implementation of realistic mathematics education. *Thinking Skills and Creativity*, *22*(7), 111–120. https://doi.org/10.1016/j.tsc.2016.09.007

Sitorus, J., Anas, N., & Waruhu, E. (2019). Creative thinking ability and cognitive knowledge: Big Five personality. *Research and Evaluation in Education*, *5*(2), 85–94. https://doi.org/10.21831/reid.v5i2.22848

Sriraman, B. (2017). Mathematical creativity: psychology, progress, and caveats. *ZDM*, *49*(7), 971–975. https://doi.org/10.1007/s11858-017-0886-0

Sukestiyarno, Y. L. (2020). *Metode Penelitian Pendidikan*. Semarang: UNNES Press.

Supandi, S., Suyitno, H., Sukestiyarno, Y. L., & Dwijanto, D. (2021). Creative thinking of prospective mathematics teacher based on learning barriers and self-efficacy. *Journal of Southwest Jiaotong University*, *56*(6), 779–793. https://doi.org/10.35741/issn.0258-2724.56.6.69

Tan, C.-S., Tan, S.-A., Mohd Hashim, I. H., Lee, M.-N., Ong, A. W.-H., & Yaacob, S. nor B. (2019). Problem-Solving Ability and Stress Mediate the Relationship Between Creativity and Happiness. *Creativity Research Journal*, *31*(1), 15–25. https://doi.org/10.1080/10400419.2019.1568155

Van Hooijdonk, M., Mainhard, T., Kroesbergen, E. H., & van Tartwijk, J. (2020). Creative problem-solving in primary education: Exploring the role of fact-finding, problem finding, and solution finding across tasks. *Thinking Skills and Creativity*, *37*(3), 1-10. https://doi.org/10.1016/j.tsc.2020.100665

Wadaani, M. R. (2015). Teaching for Creativity as Human Development toward Self-actualization: The Essence of Authentic Learning and Optimal Growth for All Students. *Creative Education*, *06*(07), 669–679. https://doi.org/10.4236/ce.2015.67067

Walia, C. (2019). A Dynamic Definition of Creativity. *Creativity Research Journal*, *31*(3), 237–247. https://doi.org/10.1080/10400419.2019.1641787

Wijaya, A. P., Nusantara, T., Sudirman, S., & Hidayanto, E. (2023). How Does Students' Prior Knowledge Differentiate Analytical Thinking Processes in Identifying the Convergence of Real Number Sequences? *International Journal of Instruction*, *16*(1), 205–218. https://doi.org/10.29333/iji.2023.16112a

Wulantina, E., Kusmayadi, T. A., & Riyadi, R. (2015). Proses Berpikir Kreatif Siswa Dalam Pemecahan Masalah Matematika Ditinjau Dari Kemampuan Matematikapada Siswa Kelas X Mia Sman 6 Surakarta [Creative Thinking Process of Students in Solving Mathematical Problems in terms of Mathematical Ability in Class X. *Jurnal Pembelajaran Matematika*, *3*(6), 671–682. https://jurnal.uns.ac.id/jpm/article/view/10724

Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving students' creative thinking skills through differentiated science inquiry integrated with a mind map. *Journal of Turkish Science Education*, *14*(4), 77–91. https://doi.org/10.36681/