Students’ creative thinking in solving geometry problems

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Abstract. Students’ creative thinking needs to be developed to help them construct new ideas in solving mathematical problems. One of the obstacles that hinder the advancement of creative thinking processes is the incompatibility of the learning approach and cognitive styles. This study aims to describe the students’ creative thinking processes in solving geometry problems based on field-dependent (FD) and field-independent (FI) models of cognitive style. Two students of Mathematics Education Study Program of Widya Mandira Catholic University Kupang participated in this study. Each participant represents different cognitive styles of the field-dependent and field-independent models. The results showed that the participant with the FI cognitive style was able to perform creative thinking processes better than the FD cognitive style participant. This can be observed at all stages. In the preparation stage, the FI cognitive style participant was more capable of expressing important ideas from the given problems; at the incubation stage, she was able to arrange ideas to solve mathematical problems by writing its detailed procedure; at the stage of illumination, she was able to express her ideas verbally; and at the verification stage, re-checking the results of her work.

1. Introduction
Mathematics is a part of science that contributes significantly to the advancement of science as well as the development of human resources. Mathematics further demands students to think logically, analytically, systematically, critically, and creatively, also equips students with the ability to work collaboratively. Therefore, mathematics instructors must place their focus and attention on the nature and characteristics of mathematics itself to design effective and efficient learning.

However, the focus and attention to create effective and efficient mathematics learning that considers mathematical creative thinking ability is still rare if non-existent. Mathematical creative thinking is essential for students to have. This skill is beneficial to acquire and utilize various information to survive in dynamic, uncertain, competitive times.

Creative thinking is a fundamental way in man to be able to understand mathematical ideas [1]. Creative thinking is a process that could generate ideas or different constructs that are transformed into new knowledge; moreover, it is the desired answer [2]. Besides, creative thinking is a mental activity that can create a different unique product [3]. Creative thinking is a process used in composing and devising a new idea [4]. Therefore, creative thinking is critical in generating an idea or new constructs for problem-solving purposes.

The creative thinking process is a real picture of how expressing creativity occurs in problem-solving [5]. Furthermore, creative thinking involves combining logical and divergent thinking [6]. Mathematical creative thinking is a process that is applied in solving mathematical problems by developing each concept in a structured, reasonable, and based on the interconnected knowledge of mathematical
contents [7]. Creative thinking is a process that generates various kinds of solutions that could be used as answers to the problems one faces. To measure student's creative thinking, the indicators developed by Wallas are commonly used [8]. These indicators consist of four stages: the preparation stage, the incubation stage, the illumination stage, and the verification stage. The preparation stage, students will prepare himself to solve the problem by clarifying the problem, collecting relevant data then reviewing it, and looking for ways to solve the problem. The incubation stage, this stage is the beginning process to inflict inspiration which is the starting point of new invention or creation from the pre-conscious area. The illumination stage, students get solution followed by inspiration and ideas that start and make a new inspiration and ide. In the last stage is the verification stage, students test and examine the solution on reality [9].

Growing and honing students' creative thinking abilities can be done by introducing a variety of challenging mathematical problems that stimulate their thinking. One of the materials that provide challenging problems that require the use of divergent thinking to find the solution is geometry [10]. Also, reported that students need to be equipped with a well-developed concept to solve geometry problems [11]. However, many students, especially those of the Mathematics Education Study Program of Widya Mandira Catholic University, have difficulty understanding mathematical concepts, notably geometry. This is because most students do not repeat what they have learned, a lack of practice in solving geometry problems, as well as a lack of understanding of geometrical concepts such as characteristics of geometric forms. One of the factors that influence this issue is cognitive style. Cognitive style affects every outcome of the thinking process that has been carried out by students.

Cognitive style refers to a way for one to process, store, and use information that has been obtained in responding to a task [12]. Furthermore, it suggests that cognitive style is a learning variable that needs to be considered in regard to learning [13]. In addition, it describes the cognitive style as a way for students to obtain, manage, and execute information in action or behaviour during the learning process in a consistent manner [14]. In summary, the description above shows that cognitive style is a way for students to capture, process, and manage information obtained in learning activities. Cognitive style can be performed and concluded as well. The cognitive styles used in this study are field-dependent (FD) and field-independent (FI). Field independent easily concentrates in various environments so that it is not easily affected by noise or confusion and it is easier to understand each word that is read or heard [15]. Other than the existence of differences in the personality characteristics of FI or FD independent individuals, there is also the existence of differences in the methods through which these two groups of people process information [16]. The justification for using these cognitive styles is that they have been widely studied; also, this study attempted to examine the basic differences of the FD and FI cognitive styles in responding to and resolving problems.

2. Method
This research is a descriptive study with a qualitative approach to analyze the data. The participants of this study are two students of Mathematics Education Study Program, one with Field Independent (FI) cognitive style, while the other one is with Field Dependent (FD) cognitive style. The research location is at Widya Mandira Catholic University Kupang. The instrument of the study is a mathematical problem-solving test aiming to determine the students' creative thinking processes in solving the problems. These indicators consist of four stages: the preparation stage, the incubation stage, the illumination stage, and the verification stage. The GEFT test was also used to group the participants based on cognitive style, and interview guidelines were used to explore the thinking process based on the stages that have been implemented. Next, to test the credibility of the data, the triangulation procedure was applied. The procedure consisted of a research instrument preparation stage when a learning style test and a problem-solving test were prepared. This stage was followed by the implementation phase and ended with the data analysis stage.

3. Results and Discussion
3.1. Field-Independent Participant’s Creative Thinking Process

The results of the data analysis on the field-independent participant's creative thinking process in solving mathematical problems can be seen in Figures 1 and 2.

![Figure 1. Field-Independent PST I Worksheet](image-url)
Based on the work done by the field-independent participant in solving mathematical problems, and the follow-up interview based on the indicators of the creative thinking process, as shown in Figure 1 and 2, the following results were obtained. At the preparation stage, the participant was able to understand the problem well and identify its important elements, which led him/her to solve the problem correctly. At the incubation stage, the participant was able to arrange ideas to solve the given problems by writing detailed procedures to achieve the solution and explaining what ideas were described in solving the problem correctly. At the illumination stage, the participant could present more than one solution to the problem and provided evidence to justify the answer's correctness. At the verification stage, the participant regularly checked her answers and accounted for her work. A general description of the field-independent participant's creative thinking process in solving mathematical problems is displayed in Table 1.

**Table 1. Field-Independent Participant's Creative Thinking Process**

| Indicator       | PST 1 | PST 2 |
|-----------------|-------|-------|
| Preparation     | √     | √     |
| Incubation      | √     | √     |
| Illumination    | √     | √     |
| Verification    | √     | √     |

*Note PST: Problem Solving Task*

The data in Table 1 suggests that the field-independent participant meets the four indicators of the creative thinking process developed by Wallas. These results are in line with the results of research conducted by [17]. The field-independent participant could perform the four steps of Polya’s problem-
solving, such as having a sound understanding of the problem, planning and taking actions that led to the correct solution, and implementing a plan to solve the given problems as well as re-checking the solution. In addition, the study conducted by [18] confirmed that field-independent participants were able to show a clear and detailed problem-solving flow. This process was completed correctly per what was asked in the problem.

3.2. Dependent Field-Dependent Participant's Creative Thinking Process

The results of the data analysis on the field-independent participant's creative thinking process in solving mathematical problems can be seen in Figures 3 and 4.

Based on the work done by the field-dependent participant in solving mathematical problems, and the follow-up interview based on the indicators of the creative thinking process, as depicted in Figure 3 and 4, the following results were attained. At the preparation stage, despite understanding the intentions of the problem, the participant could not mention its important elements. At the incubation stage, the participant was able to arrange ideas to solve the given problems by writing detailed procedures to achieve the solution; however, she was unable to explain in detail the ideas contained in the question.

At the illumination stage, the participant was unable to construct more than one solution to the problem as depicted in PST I; yet, in PST II the participant presented more than one answer to solve the problem. Also, the participant was able to provide evidence to defend the legitimacy of her answer. At the verification stage, the participant periodicity checked her solutions and accounted for her work. A general summary of the field-dependent participant's creative thinking process in solving mathematical problems is exhibited in Table 2.
Table 2. Field-Dependent Participant's Creative Thinking

| Indicator      | PST 1 | PST 2 |
|----------------|-------|-------|
| Preparation    | -     | -     |
| Incubation     | √     | √     |
| Illumination   | -     | √     |
| Verification   | √     | √     |

Note PST: Problem Solving Task

Table 2 shows that the field-dependent participant had not met the four indicators of the creative thinking process developed by Wallas. The participant was only able to meet the incubation and verification indicators. The preparation and illumination indicators were not satisfied. These findings are in line with the results of research conducted by [18]. The field-dependent participant was not able to show a clear, detailed problem-solving process. This process was not correctly completed as asked by the problem. Enforcing by the study of [19], the field-dependent participant experienced various difficulties during the creative thinking stages. At the preparation stage, the FD participant was unable to implement any creative thinking processes properly. At the incubation stage, the FD participant was not able to verbally express her ideas well. At the illumination stage, the FD participant also had difficulty in expressing her ideas to solve the given problems. At the verification stage, the FD participant experienced distress in substituting what is known to solve the problem.

4. Conclusion
Based on the results of data analysis and discussion, it can be concluded that the creative thinking process of the Mathematics Education Study Program students varies. These differences are motivated by the cognitive style they are inclined to. The participant with the FI cognitive style can execute each stage of the well-developed creative thinking process. At the incubation stage, the participant with the FI cognitive style was able to arrange ideas in solving problems by writing its procedures. At the same time, the FD participant had difficulty and lacked concentration. And at the verification stage, the FI participant regularly checked her answers, while the FD participant rarely re-checked the results of her work.

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