Use of open-ended problems as the basis for the mathematical creativity growth disclosure of student

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Abstract. Mathematical creativity is the essence of learning in mathematics. However, mathematical creativity had not yet grown among students. Means there was a gap between needs and reality. This gap must be bridged through scientific studies, and there were novel findings, namely the discovery of stages to cultivate Mathematical Creativity. The problem formulation: How to use of open-ended problems as the basis for the mathematical creativity growth disclosure of student? The goal was to use of open issues as the basis for the mathematical creativity growth disclosure of student. Research method with a qualitative approach. After data was collected then activity in data analysis, include data reduction, data presentation, data interpretation, and conclusion/verification. The results of the research: After the learning by applying the modification of RTTW learning model, then the students were trained to do the open-ended problems and by looking at the UTS and UAS values then qualitatively the results: (1) There was a significant increase of the student's final score. (2) The category of the growth of mathematical creativity of students, the Very Good there were three students, the Good there were six students, There were 17 students, and there were six students. The validation of these results was reinforced by interviews and triangulation. (3) Stage to cultivate mathematical creativity: lecturers should need to provide inputs on student work; Apply an appropriate learning creativity, and train students to work on the continuing problems.

1. Introduction

One of the abilities who students need to master in learning mathematics is possessing the strength of mathematical creativity. According to Akgul and Kahveci [1], mathematical creativity is the essence of learning math. Mathematical creativity has not been intentionally grown among the students. This means that there is a gap between need and reality, that mathematical creativity needs to grow among students, but in fact, mathematical creativity has not been grown among students by lecturers. This gap must be bridged through the real activity of finding ways to foster the Mathematical Creativity in students.

To cultivate the mathematical creativity through Discrete Mathematics lectures especially through Graph Theory, it is necessary to prepare the open-ended problems so that students can independently develop their creativity. To be able to observe the growth of the mathematical creativity, the solution of the students needs to be thoroughly examined, complete, and detailed.

The problems were: (1) How to analyze the result of the open-ended solution on the subject matter of Graph Theory and analyze the way of student completion, which can be used as supporting the growth of the mathematical creativity? (2) How was the research findings of student's Mathematical Creativity growth?
Based on the problems formulation above, then the objectives of this joint research were as follows. The aims of this study: (1) to obtain the strategy for integration of local culture in learning process of mathematics in JHS, through FGD between UNNES and UKM; (2) to obtain the experts validation, through Focus Group Discussion (FGD) between UNNES and UKM toward the draft of the Mathematics Student's Book for grade 7 of JHS that based on coastal culture; (3) produces Mathematics Student's Book for grade 7 SMP which based on coastal culture and has an ISBN, international, applicable, and in accordance with the curriculum.

1.1 Mathematical Creativity

Mathematical creativity is often called the ability of mathematical creative thinking. Mathematical means to be mathematical or related to mathematics. Mathematical creativity is the essence of mathematics. El-Sahili [2] wrote that the mathematical creativity could be defined as the ability to produce a completely original solution, generating new insights or different new answers, and allows for the new ways.

According to Nadjafikhaha and Narges [3], quite a lot of understanding of mathematical creativity was discussed or found by the mathematics education experts, including the components to cultivate mathematical creativity. Notice the following Table 1.

| No. | Expert name and Year | Discovered Theory |
|-----|----------------------|-------------------|
| 1.  | Bahar A. Kadir& Maker C. June 2011 | Indicator: If the tramp student is working on open-ended problems containing the components: *originality*, *flexibility*, and *originality*, *fluency*. |
| 2.  | Sriraman, Bharath 2013 | Indicator: If the tramp student is working on open-ended problems containing the components: *difficulty*, *fluency*, *flexibility*, and *originality*. |
| 3.  | Eric L Mann 2017 | Indicator: If the tramp student is working on open-ended problems containing the components: (1) *fluently*, (2) *flexibility*, (3) *sensitivity* (*constructive criticism of standard methods*), and (4) *originality*. |
| 4.  | Leikin, R & Lev, M. 2012 | Indicator: If the tramp student is working on open-ended problems containing the components: *fluency*, *flexibility*, *novelty*, and *elaboration*. |

1.2 Open-Ended Problems

In principle, the continuing problem is a problem which the correct answer or the algorithm is not single. This is by the opinions of Imai [4], Takahashi [5], Johari, Ibrahim, and Dalim [6] who stated that the open-ended problems are the problems that have many different answers or the issues that have some ways/Algorithms in its solution.

An open problem that has a true answer that is not singular but has a single algorithm called the open problem that has the fluency component. An open problem that has several different strategies/ways/algorithms in its solution but has a single correct answer is called an open issue that has the flexibility component.

Also, Mann [7], Bahar and Maker [8] wrote that if students can find the solution without the help of others and do not cheat when doing the problem, then the result of the solution is called the component of originality. While the issue is done in a way that is different from the usual standard way (constructive criticism of standard methods) is called a student that has the component of sensitivity.

Shen and Edwards [9], Leikin and Lev [10] wrote that if the problem who students do has nature as a new solution, the result of student solution is called having novelty component. While Sriraman [11] wrote that the problem is designed to have a level of difficulty that is "more" called a problem that has a difficulty component.
Wang [12], Yazgan-Sağ G and Emre-Akdoğan [13] wrote that the students’ solution in solving the problems done with the sequence, complete, correct, communicative, and detailed, the result of the student’s solution is called elaboration solution. Elaboration means the solution or the cultivation diligently and carefully. Careful means are thorough, complete, and detailed.

In this research, to reveal the growth of student's mathematical creativity, based on the combination of mathematical creativity theories above, using open-ended problem which contains four related components, namely fluency, flexibility, elaboration, and originality component. Furthermore, the four components were grouped into two qualitative scoring patterns, namely: (1) Open-ended with fluency components whose solution was done elaboration, and originality; or (2) The open-ended problem with the flexibility component whose solution was done elaboration, and originality.

The following are examples of open-ended questions in Graph Theory that can be used to foster students' mathematical creativity:

1) Open-ended problem that has more than one right answer

  Given: The sequence of $\pi$, whose the terms are the vertices of a Graph, are $\pi = (4, 2, 4, 6, 7, 4, 1, 3, 5, 4)$.

  Asked: Some variations of the graphic of a simple graph, drawn in sort from graph $\pi_5, \pi_4, \ldots, \pi_1$, to $\pi$.

  Answer:
  - The degree sequence of a graph, $\pi = (1, 3, 4, 3, 5, 4, 3, 3, 4)$ or $\pi = (5, 4, 4, 4, 3, 3, 3, 3, 1)$.
  - The largest number is gradually eliminated with the assumption that the vertex corresponds directly to the vertices that have degrees below.
  - The degree sequence of a graph to be $\pi_1 = (3, 3, 2, 2, 2, 3, 3, 1)$ or $\pi_1 = (3, 3, 3, 2, 2, 1)$.
  - The largest number is gradually eliminated, $\pi_2 = (2, 2, 2, 2, 2)$ or $\pi_2 = (3, 2, 2, 2, 2, 1)$.
  - $\pi_3 = (1, 1, 1, 1, 1)$, or $\pi_3 = (2, 2, 1, 1, 1)$.
  - $\pi_4 = (1, 0, 1, 1, 1)$, or $\pi_4 = (1, 1, 1, 1)$.
  - $\pi_5 = (0, 1, 1, 0)$, or $\pi_5 = (1, 1, 0, 0)$.

![Figure 1](image)

**Figure 1** Some figure of the simple graph who students may make were as follows

2) Open-ended problem that has more than one right algorithm

  Given a graph $G_i$ as the Figure 2 below.
2. Methods
In this research used research method with a qualitative approach. Miles and Huberman [14] suggested that the activity in qualitative data analysis interactively done so that data is appropriate for its purpose. The technique of analysis through data collection, data reduction, data display, data interpretation, and conclusion. The process of reading of data used to reveal the growth of mathematical creativity based on the results of triangulation.

3. Result and Discussion
To analyze the results of the open-ended solution on the subject matter of Graph Theory and to analyze the method of student solution, which can be used to reveal the growth of mathematical creativity was as follows. Based on the results of the exercise when the students practice to solve the problem of open-ended, (1) students who were skilled at solutions on open issues with the fluency component did not guarantee skilled also in working on open-ended problems with flexibility components, and vice versa. (2) Based on the consideration of point (1) above, the category selection was taken for the best result on the fluency component that was done by elaboration and originality, or on the best result of the flexibility component that done by elaboration and originality. (3) The way in which the researcher selected applies only to this study and to the consideration of the academic atmosphere present in this research class.

As the discussion, the findings of research on the growth of Mathematical Creativity of students were as follows. Notice Table 2.

| No. | Categories of Growing the Mathematical Creativity | The number of Students |
|-----|--------------------------------------------------|------------------------|
| 1.  | Very Good                                        | 3                      |
| 2.  | Good                                             | 6                      |
| 3.  | Enough                                           | 17                     |
| 4.  | Less                                             | 6                      |
| 5.  | Very Less                                        | 0                      |

From Table 2 mentioned above, it appears that the tendency there was about 9.375% of students who had grown their mathematical creativity with the Very Good category. Also, there was approximately 18.75% of students who had grown their mathematical creativity with the Good category. Then there was about 53.125% of students who had grown their mathematical creativity with Enough category, and there was about 18.75% of students who had grown their mathematical creativity with Fewer categories. Students with the category of Very Less, not found.

4. Conclusions
To analyze the results of the open-ended solution on the subject matter of the Graph Theory to reveal the growth of Math Creativity, it was taken for the best results on the fluency components employed in
elaboration and originality, or on the best solution on the flexibility components used in discussion and originality.

The tendency was about 9.375% of students with Very Good of their mathematical creativity. There was about 18.75% of students with Good of their mathematical creativity. There was approximately 53.125% of students with Enough of their mathematical creativity, and there was about 18.75% of students who had their mathematical creativity with Fewer categories

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