Graph theory as a tool to track the growth of student's mathematical creativity

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Abstract. The essence of studying mathematics is the growth of mathematical creativity. The candidate of mathematics teachers need to know how to cultivate the mathematical creativity to students at school. The problem: How to cultivate students' mathematical creativity through Graph Theory learning as the subject of lecturing? The goal, using Graph Theory as a tool to track the growth of mathematical creativity of students. The research method with qualitative approach which data analysis include: data reduction, data presentation, data interpretation, and conclusion/verification. The results of this research: (1) Graph theory can be used as a tool to cultivate the students' mathematical creativity, by applying it to the open ended problems. (2) Based on the solution of the open ended problems, interviews, and triangulation, the students' mathematical creativity can be grown. (3) The growth of students' mathematical creativity has the Good categorical tendency. Suggestions: (1) The students need to be motivated about the importance of mathematical creativity. (2) The growth of mathematical creativity should be tracked also through other the subjects lecturing.

1. Introduction

One of the skills who students need to master in learning mathematics is possessing the ability of mathematical creativity. Math-related creativity, often called mathematical creativity. Mathematical creativity is the essence of learning mathematics.

The growth of a person's mathematical creativity or even from the beginning of the process of working on a problem must clearly be preceded by their ability to engage in reading, thinking, speaking/give an opinion, and their ability to write their findings. Learning model that is considered suitable for early supporters of the growth of this mathematical creativity, can be submitted to the wisdom of lecturers who teach.

To cultivate mathematical creativity through Discrete Mathematics lecturing especially through Graph Theory, it is also necessary to prepare open ended problems. To be able to observe the growth of mathematical creativity, the work of students in working on open ended problems needs to be done thoroughly, completely, and independently.

Based on the background above then the problem is as follows. How to cultivate students' mathematical creativity through Graph Theory learning as the subject of lecturing?

Based on the background and problem formulation above, the purpose of this study is as follows. The purpose, using Graph Theory as a tool to track the growth of mathematical creativity of students.

In learning mathematics, one of the abilities that need to be mastered by learners, is possessed the ability of mathematical creativity. No exception for the students. Affirmed by [1-3] that understanding of creativity is essential for teachers/lecturers because, through understanding, teachers/lecturers will
have a guide in designing and implementing training programs specifically to foster the creativity of students or university students.

Furthermore, [4-6] wrote that mathematical creativity can be defined as the ability to produce completely original work, generate new insights or different new answers, ways. Thus, mathematical creativity is an act of thinking that can generate creative ideas, new ways of thinking, and original in the field of mathematics. This creativity refers to the ability to think more one step ahead and is the product of one's ideas.

The growth of mathematical creativity, could ensure the growth of overall mathematical ability, affirmed by [7,8]. There are factors that can be a barrier to the growth of mathematical creativity in the student. The obstacles are as follows. (1) **Student as a threat.** Students who have mathematical creativity are viewed as threat by their teacher. (2) **Attitudes of Parents.** The attitude factor of this parent will arise when parents of students who have mathematical creativity stop or hinder students in participating in some activities. (3) **Syllabus of School.** In the school syllabus, no allocated time is given to students who have mathematical creativity. (4) **Teacher:** Teacher factors can also inhibit the growth of mathematical creativity. It has been found that students who have divergent and more creative thinking are likely to be far away or shunned by their teachers. (5) **The Individual:** Students who have mathematical creativity can be an obstacle to themselves if the student accepts teachers and textbooks as the ultimate authority. (6) **Lack Self Confidence.** A sense of lack of confidence can also be another obstacle.

In principle, open-ended problems are a matter of which the answer is correct or the algorithm is not single. So, [9] stated that open-ended problems are problems that have many different answers or problems that have some way/algorithm in the solution. The use of open-ended problems will give students a rich source of experience in interpreting the problem.

In mathematics, the terms in mathematics are often different from the terms in everyday life. The term Ring or Field in Algebraic Structure differs from the ring or field in everyday life. In everyday life, the ring means ring for our finger, and field means field for sport. So also, with the term of fluency and flexibility in the open-ended problems.

While [10,11] wrote that open-ended problem were as follows. (1) An open-ended problem that has a correct answer that is not singular but has a single algorithm called open-ended problem that has a character of fluency component. (2) An open-ended problem that has several different ways/algorithms in its completion but has a single true answer is called an open-ended problem that has the character of flexibility component. In addition, if students can find a solution, without the help of others, the solution is the work of their selves, while working on the question of not asking to the other persons, and not doing cheating while working on the problem, then the results of the work is called to have components of originality. While the work of students in solving the problems done with the sequence of steps, complete, correct, communicative, and detailed, then the work of the students is called work that is elaboration. Elaboration means workmanship done by carefully. Careful means thorough, complete, and detailed.

In this research, to reveal the growth of student's mathematical creativity, using open-ended problem which contains four related components, namely fluency, flexibility, elaboration, and originality component. Furthermore, the four components are grouped into two qualitative scoring patterns, namely: (1) Open-ended problem with fluency components whose work is done elaboration, and originality, or (2) open-ended problem with flexibility component whose work is done elaboration, and originality.

2. **Methods**

This research used research method with qualitative approach, which has natural characteristic as direct data source, descriptive, and process more important, in finding something to get accurate result.

The subjects of this research were the selected students that their the problem solution would be interviewed about the result. Students who as the subject of research came from the Mathematics Education Study Program of FMIPA of Universitas Negeri Semarang. To the students of this class: (1)
Graph Theory was given as the first step to grow mathematical creativity and students were trained with open-ended problems; (2) Students were given open-ended problems on the subject matter of Graph Theory which contained fluency components that must be done in elaboration and originality; and flexibility which must be done elaboration and originality also; (3) in this research, open-ended problem containing fluency component and done by elaboration and originality, or open-ended problem that contains flexibility component and done elaboration and originality is used to determine the growth indicator of student mathematical creativity; (4) Research team analysed in depth the growth of mathematical creativity of the students through intensive open interviews that were continued with triangulation.

Data analysis in this study, used the rules of Matthew B. Miles & A. Michael Huberman. In this case. [12] argued that the activity in qualitative data analysis is done through data collection process, then data reduction, display data, data interpretation, and conclusions.

3. Results and Discussion

The results of the recapitulation of student solutions related to open ended problems with the components of fluency or flexibility were done with elaboration and originality were as follows.

After the lecturer gave the material, then the students were given open-ended problems. Furthermore, after being corrected by the lecturer, the initial table of findings was as follows. Look at the following Table 1.

| Score with Range | Number of Students |
|------------------|--------------------|
| 86 – 100         | 7                  |
| 81 – 85          | 12                 |
| 71 – 80          | 10                 |
| 66 – 70          | 3                  |
| 0 – 65           | 0                  |
| Total            | 32                 |

In Table 1 above, the acquisition of the students score based on the assessment rules of Universitas Negeri Semarang.

Furthermore, based on the analysis of the results of tests on student above, then continued with interviews and triangulation, then obtained the results were summarized and reduced in the following Table 2.

| No. | Categories of the Growth of Mathematical Creativity | Number of Students |
|-----|---------------------------------------------------|--------------------|
| 1.  | Very Good                                         | 3                  |
| 2.  | Good                                              | 17                 |
| 3.  | Enough                                            | 9                  |
| 4.  | Less                                              | 3                  |
| 5.  | Very Less                                         | 0                  |

Reducing for obtaining the results in Table 2 were as follows. (1) Based on the results of the exercise when the students practice to solve the problem of open-ended, students who were skilled at working on open-ended problems 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 best results on the fluency components employed in elaboration and originality, or on the best results on flexibility components
employed in 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.

The results of this research, Graph Theory can be used as a tool to cultivate the students' mathematical creativity, by applying it to the open ended problems. The growth of students' mathematical creativity had the Good categorical tendency.

Based on the results of the research above, then the following would be discussed the results of this research. Revealing the growth of mathematical creativity of the student, the problems given in the form of problematic problems. Problem is problematic, means that the algorithm of problem should not be given to students first. The solution of the problem can be non-routine, can have some correct answers, or can have several different algorithms. Through the problematic problems, it was expected that the students got the opportunity to develop their ideas and creativity in doing every problem thoroughly, clearly, and correctly.

Furthermore [13,14] wrote that mathematical creativity is indispensable to students, even math teachers. In addition, many experts argued that to cultivate mathematical creativity requires an open-ended problem. Therefore, the lecturers' desire to cultivate mathematical creativity for their students requires the support of prerequisite capabilities for lecturers that must be able to make open-ended questions, both containing fluency or flexibility components. Lecturers also have to train students to get used to solution on a problem by complete, sequential, and communicative. Lecturers also need to select and apply an appropriate learning model to support the growth of mathematical creativity.

The power or benefit of mathematical creativity is very important for students because it can increase students' absorption while learning math and practice doing the math problems. Thus, mathematical creativity needs to be developed in school or at college, at all levels.

4. Conclusion
Based on the results of research and discussion as described above, the conclusions that can be drawn from this research are as follows. (1) The form of open-ended problems on the subject matter of Graph Theory and the way of completion, can be used as a supporting indicator of the growth of mathematical creativity. (2) Graph theory can be used as a tool to cultivate the students' mathematical creativity, by applying it to the open-ended problems. (3) Based on the solution of the open-ended problems, interviews, and triangulation, the students' mathematical creativity can be grown. (4) The growth of students' mathematical creativity has the Good of categorical tendency.

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