Research Article

Assessing Students' Mathematical Creativity in Learning with STEM Contexts on Practical Problems of Derivative Applications

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Abstract.
Providing opportunities by freeing students to explore learning mathematics is an implementation of creativity. In order to improve mathematical creativity, it is necessary to use an interdisciplinary approach to learning various mathematical concepts with the application of Science, Technology, Engineering, and Mathematics (STEM) principles. This study aims to describe students' mathematical creativity in learning with STEM context on practical problems of derivative applications by using the descriptive research analysis method. This study uses a qualitative approach with stages covering problem formulation, sample selection, research limitations, instrumentation, data collection and analysis, and conclusion. The subjects of this study were students of the 4D Mathematics Education Class with a sampling technique that was purposive sampling in terms of self-efficacy. The analytical techniques carried out for STEM learning were pretest, posttest, self-efficacy questionnaire, and student response questionnaires. The results of this study indicate that learning with the STEM approach can increase students' mathematical creativity in solving practical problems of derivative applications. This shows that the STEM approach can equip students to be creative and resilient in dealing with various problems and changes that occur in the future.

Keywords: mathematical creativity, practical problems of derivative applications, stem.

1. INTRODUCTION

The development of the times in the 21st century demands learning that can integrate literacy skills, knowledge skills, skills, and attitudes, as well as mastery of technology. Of course, this requires strong and capable human resources in mastering various forms of skills including creative thinking and problem-solving skills so that they can become good problem solvers in answering the problems found. The framework by 21st Century Skills emphasizes that 21^{st}-century learning must teach 4 competencies, namely communication, collaboration, critical thinking, and creativity [1]. Lian defines

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creativity as the ability to think about things in new and unusual ways and come up with unique solutions to problems [2]. In line with that [3, 4], creativity is an intellectual ability that can give rise to creations, inventions, and discoveries that bring new relationships, entities, and/or unexpected solutions into existence.

Creativity is divided into two forms that are seen from the cognitive (aptitude) and non-cognitive (non-aptitude) sides. Cognitive characteristics of creativity consist of originality, flexibility, and fluency. While the non-cognitive characteristics of creativity include motivation, personality, and creative attitude [5, 6]. Good creativity includes cognitive and non-cognitive characteristics and is one of the important potentials to be nurtured and developed. Another definition of creativity can be seen from four components, including person, process, product, and press. This understanding became known as the "Four P's of Creativity". [7, 8]. Furthermore, it is explained that as a person, creativity means non-cognitive personality traits inherent in creative people; as a process, creativity means the ability to think to make new combinations; as a product of creativity is defined as a new work, useful and can be understood by the public at a certain time; and as a press, it means that the development of creativity is determined by both internal and external environmental factors.

There are two key elements of creativity, specifically novelty (i.e. original, unique, new, fresh, different creation) and usefulness (i.e. valuable, meaningful, relevant, appropriate, valuable creation) [9]. The combination of these two elements serves as the key to scientific discussion and the definition of creativity. Furthermore, mathematical creativity contains three important aspects, including fluency, flexibility, and originality [10]. Fluency in thinking refers to the quantity of output. This relates to the number of original ideas generated. So that it can be described as fluency is the ability to generate a large number of ideas, consequences, or possibilities, and can generate different thoughts and hypotheses related to problems involving one's mind. Fluency also means the ability to select from available valuable ideas from many different dimensions for a particular purpose. Meanwhile, flexibility in thinking refers to changes such as changes in the meaning, interpretation, or use of something, changes in task understanding, changes in strategy in performing tasks, or changes in the direction of thinking, which may mean interpretations of new results. Originality in thinking means the production of unusual or one might say rare, implausible, remote, or clever responses. In addition, original ideas must be socially useful. Originality can be explained statistically as rare answers, occur only occasionally in a given society, and are considered original. Meanwhile, another opinion says that the aspect of creativity can be seen in fluency, flexibility, originality, and elaboration [11]. From the descriptions of creativity from some of these experts, it can be concluded that creativity is a mental activity that is carried out by a person in producing new solutions to a problem which includes aspects of fluency, flexibility, originality, and elaboration.

In its application, mathematical creativity can be seen from the capability to solve mathematical problems. Creativity occurs through a series of small steps in which previous ideas are modified and developed. The nature of creativity occurs when the problem solver goes to an obstacle, proposes a solution, walks to a further obstacle, and then refines and elaborates on the previous solution. The relationship between mathematical creativity and problem-solving abilities starts from formulating mathematical goals and discovering their innate relationship which is the ability to solve problems by integrating both the nature of logical inference in mathematics education and the evolving concepts that are at its core. Creativity is also often associated with the context of problem formation (problem finding), invention, independence, and originality. A person is said to be creative if he is able to find a new solution to a problem and make a complex and new synthesis [12]. Another opinion also says that creative people can assess problems from various points of view so that it becomes a better solution. Different points of view stimulate various ideas and develop new cognitive structures. With creativity, a person can think divergently and convergently in solving problems. Thus, it can be concluded that creativity is a multifaceted construct that involves divergent and convergent thinking in finding and solving mathematical problems.

To support student achievement in developing their creativity, it is necessary to have learning that can help students become more creative. One of the lessons that can accommodate mathematical creativity is learning in the context of Science, Technology, Engineering, and Mathematics (STEM). The application in this research is also associated with the stage of solving problems in contextual form in four different fields, namely Science, Technology, Engineering, and Mathematics (STEM). Learning in the STEM context provides integrated knowledge from various disciplines in solving real-world problems which in practice are very complex and interdisciplinary [13]. For the successful application of STEM in the classroom, students must be able to maintain interest and motivation to be actively involved in STEM learning. In addition, lecturers must also be equipped with good quality pedagogical abilities so that they can positively influence student attitudes in applied STEM learning [14]. In relation to STEM, it can be said that mathematics is the main foundation in STEM. Mathematics can be thought of as a set of tools for various disciplines. When combined with science in a problem can be classified as follows, mathematics focuses on “problem solving” while science focuses on “investigation” [15]. In order to better connect mathematics and other disciplines in STEM, it is necessary to focus on ideas and thinking development in mathematics.

Based on the explanation of the importance of mathematical creativity and its relation to STEM learning, this research will focus on describing students’ mathematical creativity in learning with STEM contexts in solving mathematical problems, especially derivative applications.

2. RESEARCH METHOD

This study aims to describe students’ mathematical creativity in learning with STEM contexts on practical problems of derivative applications. The subjects of this study were students of Mathematics Education, Mataram University Class 4D who took the Advanced Calculus course for the 2021/2022 Academic Year. This research method is descriptive. Descriptive research is research that guides researchers to explore and photograph social situations thoroughly, broadly, and deeply. The selection of this method is based on the consideration that the data that describes the mathematical creativity of students are selected based on the level of self-efficacy of the upper and middle groups. The data collection technique is through tests, observations, and interviews. Meanwhile, the data analysis technique used is the Miles and Huberman Model with the steps of data reduction, data presentation, and drawing conclusions. The data collected in the form of self-efficacy questionnaire data, mathematical creativity, and student response data to the STEM learning carried out. Thus, the instruments used were self-efficacy questionnaires, pretest and posttest of mathematical creativity, and student response questionnaires in STEM learning. The location of this research is in Mathematics Education Study Program, Faculty of Teacher Training and Education, University of Mataram. The procedure of this research is shown in Figure 1.

To measure mathematical creativity in solving problems, it must be determined based on several indicators as shown in Table 1 as follows.

Meanwhile, the classification for student responses to STEM learning is carried out using the criteria in Table 2 as follows.

3. RESULTS AND DISCUSSION

The results of this study are in the form of research instrument data such as the results of student creativity tests and the results of student responses to STEM learning that has been carried out. All the instruments used in this study have been validated by

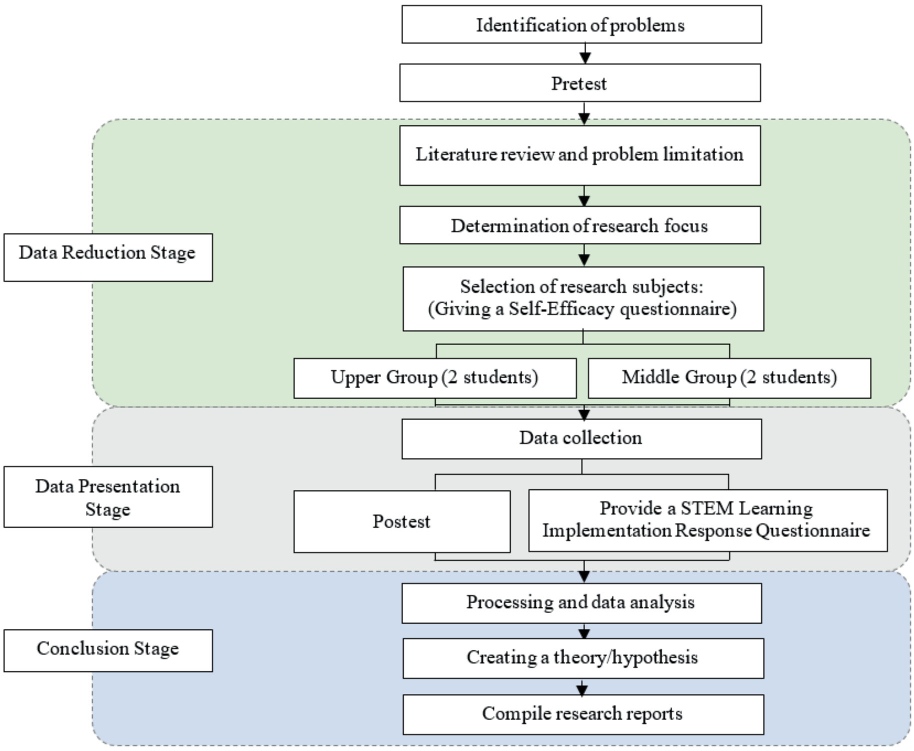

Figure 1: The research flowchart.

TABLE 1: The Indicators of student mathematics creativity in problem solving.

The Stages	**The Indicators**
Generating	observe/translate the problem, collect and organize information, remember the concepts/natures/principles related to the problem and relate them, build conjectures or hypotheses ideas/problem problem-solving
Planning	choose an idea or method that is considered appropriate designing ideas;
Producing	apply design ideas, evaluate/test solutions
	write valid conclusions

TABLE 2: Category of student response to learning.

Average score	**Category**
$\underline{R_T} \geq 2$	Positive response
$\underline{R_T} < 2$	Negative response

expert validators and practitioners and it is concluded that the instrument is valid and slightly revised so that it can be used by improving according to the written suggestions. The results of the student creativity test can be shown from the pretest and posttest as shown in Table 3 as follows.

Table 3: Results of student pretest and posttest analysis.

	Pretest	Postest
Minimum score	37.04	62.96
Maximum	77.78	96.30
Total Average	58.44	81.07
The percentage increase		22.63%

Table 3 shows an increase of 22.63% after getting learning using STEM so it can be concluded that STEM learning is effective to be applied in increasing mathematical creativity in solving practical problems of applying derivatives. Other studies also show that learning with a STEM approach can increase students' mathematical creativity [16, 17].

Furthermore, the class is classified based on the level of self-efficacy possessed by students who receive learning in a STEM context. Based on the results of the self-efficacy questionnaire analysis, the classification of self-efficacy levels is obtained as shown in Table 4 as follows.

Table 4: The results of the classification of students' self-efficacy levels.

Self-Efficacy Level	Number of students	Percentage
Upper group	13	36,11%
Middle Group	21	58,33%
Lower Group	2	5,55%
Total	36	

Based on Table 4 shows that of the 36 students who are included in the self-efficacy of the upper group, there are 13 students, which is 36.11%. Meanwhile, the number of students who have self-efficacy in the middle group is 21 students, which is 58.33%. While students who have a level of self-efficacy in the lower group are only a few, namely 2 people or 5.55%. Based on the consideration of the number of students at several levels of self-efficacy, the sampling technique used in this study was purposive random sampling. In this study, the research subjects were 2 people with the highest total score in the upper group and 2 people with the highest score from the middle group. Furthermore, the results of the scoring on the categorization of students' intelligence set 4 subjects for each criterion. The main research subjects are shown in Table 5 as follows.

Furthermore, each research subject was given a pretest to determine the students' initial mathematical creativity before being given treatment in the form of learning with a STEM context. The following are the results of written test triangulation from MU-1

Table 5: Main research subjects.

Student Category	Selected subject
Students with self-efficacy levels are in the Upper Group category	MU-1
	MU-2
Students with self-efficacy levels are included in the Middle Group category	MM-1
	MM-2

and MU-2 which are included in the category of students with self-efficacy levels in the Upper Group category as shown in Table 5.

Examples of open-ended problems used in this study are as follows.

Open-ended Problem:
Andi's toy boat slips from his grasp at the edge of a straight river. The stream carries it along at 5 meter per second. A crosswind blows it toward the opposite bank at 4 meter per second. If Andi runs along the shore at 3 meter per second following his boat, how fast is the boat moving away?

Figure 2:

The questions were done by students with self-efficacy abilities in the upper and lower groups. The results of triangulation of mathematical creativity on the subject of MU-1 and MU-2 with the level of self-efficacy of the upper group in working on these questions are presented in Table 6.

Table 6 shows that students with upper group self-efficacy can formulate problems, plan, and implement plans smoothly, and create creative ideas so that effective, complete, and precise answers are obtained. Other studies also mention that good self-efficacy affects students' creativity [18]. Meanwhile, the results of triangulation of answers to the mathematical creativity test of students who have a middle group level of self-efficacy can be seen in Table 7 as follows.

Table 6: Results of triangulation of student's mathematical creativity with upper group self-efficacy.

Indicators	MU-1	MU-2	Conclusions
Generating Problem	Able to translate problems using analytical reasoning, write down what is known, and be asked fluently and completely	Translating the problems contained in the questions using analytical reasoning, writing down what is known, and asked fluently and completely.	Able to formulate problems coherently and completely.
Planning	Write down the method to be used with the right formula. MU-1 does this by using the chain rule formula.	Write down the working method to be used. MU-2 does this by drawing an illustration that matches the problem.	Able to choose and plan appropriate and effective problem-solving methods.
Producing	Implement the planned strategy, re-examine the results of the answers, and write the conclusion of the answers. MU1 can write down 3 correct answers, namely by testing $t = 1$, $t = 2$, and $t = 3$.	Implement the planned strategy, re-examine the results of the answers, and write the conclusion of the answers. MU2 can write down 2 correct answers, namely by testing $t = 1$ and $t = 2$.	Able to implement problem solving plans and create unique ideas that are effective and produce correct answers.

Table 7: Results of triangulation of student's mathematical creativity with middle group self-efficacy.

Indicators	MM-1	MM-2	Conclusions
Generating Problem	Able to translate problems using analytical reasoning, write down what is known, and be asked in full.	Translating the problems contained in the questions using analytical reasoning, writing down what is known, and asked in full.	Able to formulate problems well but not coherently in implementation
Planning	Write down the method to be used with the right formula. The MM-1 does this by using a drawing illustration and a chain rule formula.	Write down the working method to be used. MM-2 does this by drawing an illustration that fits the problem and applying the Pythagorean formula.	Able to choose and plan the right solution method.
Producing	Implement the planned strategy, write down the conclusion of the answer, but do not re-examine the results of the answers obtained. MM1 can write down 2 answers but make a calculation error so that the resulting answer contains a few errors.	Implement the planned strategy and write down the conclusions of the answers, but do not re-test the answers obtained. MM2 can only write 1 correct answer, namely t=3 but there is a slight error in writing the unit of speed.	Able to implement ideas and completion plans quite well but there are some missed steps and calculation errors made.

Table 6 shows that students with lower group self-efficacy tend to be less coherent in formulating problems, able to choose and implement a good problem-solving plan, but do not go through the stages of re-examination (looking back) the answers that have been obtained so that there are few errors in calculations and writing. speed unit. Other studies also mention that students with less self-efficacy tend to be hesitant about the chosen strategy and are not sure of their answers so that there are some mistakes made [19]. The following is a description of the flow of thinking of students' mathematical creativity with Upper Group Self-Efficacy, namely MU-1 and MU-2, and students' mathematical creativity with Middle Group Self-Efficacy, , namely MM-1 and MM-2, in solving practical problems of derivative applications as shown in Figure 2.

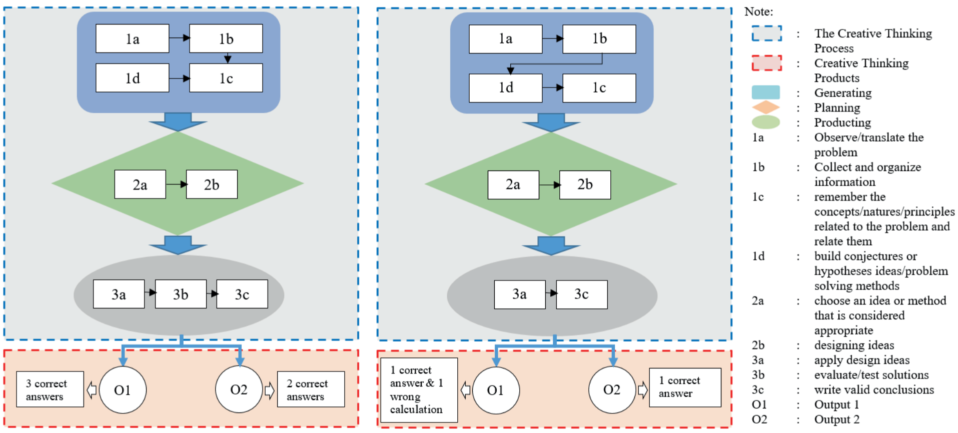

Figure 3: Description of the flow of thinking of students' mathematical creativity with a) Upper group self-efficacy b) Middle group self-efficacy.

Figure 2a) shows that students with upper group self-efficacy abilities worked on open-ended questions with coherent problem-solving steps, did not make calculation errors, and obtained more than one answer. By with previous research that students with high self-efficacy have good confidence to answer questions and are not afraid to try new things in order to obtain effective and efficient final results [20, 21]. Meanwhile, Figure 2b) shows that students with medium self-efficacy tend to be disorganized in applying problem-solving steps, skipping several stages such as the re-examination stage, and only getting one correct final result. This is in accordance with previous research that students who lack self-efficacy tend to be unsure of the final results obtained and find it difficult to accept challenges such as open-ended problems that have been experienced [22].

4. CONCLUSION

In this study it can be concluded that (1) Students' creative abilities after applying learning in the STEM context were completed classically with an average of 81.069; (2) The average value of student creativity increased by 22.63%. This means that learning with STEM contexts is effective for developing students' mathematical creativity; (3) The mathematics creativity of students for the self-efficacy category of the upper group meets all aspects of creativity very well, starting from generating, planning, and producing; (4) Students' mathematical creativity for the self-efficacy category of the middle group met all aspects of creativity well, but the production section did not carry out evaluation indicators/test solutions and write valid conclusions and some calculations were carried out; and (5) The student's response to the learning that was carried out had an average score of 2.38 and was included in the positive category.

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