Investigating Students' Mathematical Creative Thinking Skill Based On Academic Level And Gender

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Abstract: This study aimed to describe students' mathematical creative thinking skills based on academic level and gender in complex analysis course. This study was naturally qualitative and therefore the data collection techniques were in the forms of data test and interview. The participants were 112 undergraduate students in Mathematics Education Department in Pekanbaru, Indonesia who were taking Complex Analysis course. Based on gender, the result revealed that there was a difference in mathematical creative thinking between male and female students in solving problems of square root complex equation. Furthermore, based on academic level, the result showed that the students' mathematical thinking skills were in high, moderate, and low level. This result indicated that the students were able to solve problems in mathematics by their own way. However, they had not yet been able to demonstrate detail procedures to overcome those mathematical problems.

Index Terms: mathematical creative thinking skill, academic level, gender.

1 INTRODUCTION

Creative thinking is one of the most important high-level thinking skills to develop in the 21st century [34]. One alternative that should be developed is enhancing higher order thinking skills via assessment [4]. In mathematics course at the university, the creative thinking skill is critical to prepare university students who are logical, critical, creative, and systematic. Likewise, the creative thinking skill is an avenue to produce graduates who have responsiveness, diligence and responsibility. In Indonesia, this way of creative thinking has provided a space to develop in learning process as it is stated in the decree of the Ministry of National Education No. 41 in 2007 on the Standard Process [9]. The decree expounds that the process of learning in the educational unit is organized in an interactive, inspiring, fun, and challenging ways, to increase learners' activeness and become the place for innovation, creativity, and independence in accordance with the learners' talents, interests, and physical and psychological development. Johnson [14] states that creative thinking is a habit of mind trained based on intuition, imagination, new possibilities, fresh perspectives, and unexpected ideas. [33]; [22] further expounds that creative thinking has four components: fluency, flexibility, originality, and elaboration. In addition, [3] explain that "creative thinking is another type of thinking of interest to educators. This type of thinking is normally associated with cognitive skills and abilities for coming up with novel solutions to problem situations". Besides, in practice, when students learn at their own initiative, given the confidence to think and put forward new ideas, their ability to think creatively emerges. In classroom setting, mathematics learning to foster creative and high-level thinking is in the light of cooperative learning. This is to make students interact one another and therefore evoke effective strategies to solve problems using a scaffolding technique.

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Based on the above discussions, it is inferred that creative thinking skill is vitally important to enhance students' achievements in mathematics. This is because through mathematical creative thinking, students can organize mathematical thinking in the learning process. [7] creative thinking in math is closely related to the students ability in solving routine problems.This is based upon the notion of [6] postulating that creativity is a process a continuous, dynamic, circular three-phase process of finding good problems, solving them and implementing good solutions. [32] gives a solution that the natural environment can be an inspiration for creative thinking. One of the major problems in education is low achievement and optimalization of students' thinking skills. This rule out the nature of people thinking which upholds the combination of ability to think and skill. Therefore, the thinking skill should have been developed at early age, so that there will be no developmental obstacles in college. Considerable experts assert that the creative thinking in mathematics is a combination of logical thinking and divergent thinking which is derived from intuition, consciously, which takes into account the flexibility, fluency, and novelty, [23]; [18]; [26]. Furthermore, [21] expounds that creativity is an ability to reflect fluency, flexibility and originality in thinking and an ability to elaborate an idea. Creative thinking is often defined as divergent thinking. This is based upon the views of Guilford [15], "it is in the divergent-thinking category that we find that are most significant abilities in creative thinking and invention. Furthermore, [15] describe four aspects of divergent thinking, namely fluency, originality, flexibility, and elaboration. This is further elaborated by [35] that: Included in the divergent thinking category were the factors of fluency, flexibility, originality, and elaboration. Based on the afformentioned opinions, the mathematical creative thinking ability is the ability that includes four aspects: (a) fluency, the ability of student to provide a lot of ideas, and solve problems with the right answer; (b) flexibility is the ability of students to solve problems in one way, then in another manner; (c) Originality is the ability of students to solve problems in its own way; and (d) elaboration, the ability to solve the problem by performing the steps in detail. Square root of complex numbers is a subject matter in complex analysis course at university. This subject matter requires a high level of skill to determine the roots of complex numbers and argument of the complex number. One

of the basic concepts underlying the study is the application of De'Movre and Euler formula. At that point, cognitive conflict force students to think creatively in finding solutions to problem. Consequently, the students' answer can be varied by using the basic concepts of the course on the other. In the next stage, the basic concept of the square root of complex numbers can be applied to the verification of analytic functions and harmonic functions, as it is said by [28], that the basic concept previously the basis for the subsequent material application. Pondering the academic level and gender, researchers predict that everyone is naturally creative, the different is only in the level of creativity. The idea of the level of creative thinking has also been disclosed by previous researchers. De Bono [5] describes four levels of achievement of the development of creative thinking skills. These are awareness of thinking, observation of thinking, thinking strategy, and reflection on thinking. Similarly, [30] describe that, in general, the mathematicians' creative processes follow the four-stage Gestalt models of preparation, incubation, illumination, verification. Likewise, the findings of [27] and [26] exist to suggest that students' mathematical creative thinking in the classroom is based on a certain level. Therefore, this study is to describe students' mathematical creative thinking skills in square root of a complex equation based on academic level and gender.

2 METHOD

This study was naturally qualitative. Participants were students of the 6th semester at academic year of 2015/2016 from Mathematics Department of Riau Islamic University as many as 112 university students (18 men and 94 women). The participants were divided into three groups in terms of students' academic level, low (18 students), moderate (82 students) and high (12 students). The instruments were in the forms of the test and interview. The instrument of creative thinking abilities was a set of essay tests. The validity of instrument is a precision to measure what should be measured through the items on the instrument [2]. In this study, the validity of intrument was content and face validity. Besides, the reliability of instrument refers to the sense of whether an instrument can measure something consistently over the time. In this study, the reliability of instrument used Cronbach alpha [10]. Data analysis technique was qualitative descriptive analysis.

3 RESULT OF RESEARCH

The research data of this study were in the form of data description about the test of creative thinking ability of students in the mastery of complex analysis particularly on square root of a complex equation. The data analysis was performed by describing the subjects' answer and result of interviews. Furthermore, in the last stage, the researchers used triangulation of data to synchronize between the data results of tests and interviews. After the subjects worked on mathematical creative thinking test, the researchers further classified the students based on their academic level and gender and determined the average and maximum scores of each level and gender.

3.1 Grouping Students of Creative Thinking Ability Based on Academic Level and Gender

The summary of critical thinking ability based on academic level and gender are presented in Table 1.

TABLE 1.
GROUPING STUDENTS OF CREATIVE THINKING ABILITY BASED ON ACADEMIC LEVEL AND GENDER

Ability Level	Male	Mean	Maximum Score	Female	Mean	Maximum Score
High	2	97	100	10	81.2	93
Moderate	11	70	83	71	78.4	97
Low	5	59	71	13	68.5	79
Summary	18	75.33		94	76.03	

Source: *Data Researchers*

3.2 Profile of Student Creative Thinking Ability in Solving Problem based on Academic Level and Gender

Based on the following indicators fluency, flexibility, originality and elaboration, the researchers describe the results of triangulation of students' written test and interview based on academic level and gender. The summary of the description are presented in Table 2, 3 and 4.

TABLE 2.
PROFILE OF STUDENT CREATIVE THINKING ABILITY ON HIGH LEVEL ACADEMIC

Level of Academic Ability		High	
Gender		Male	Female
Indicators of Creative Thinking Ability	Fluency	Being able to interpret the graphic of θ score or in direct way. Being able to determine the solution of root of complex equation	Being able to interpret the graphic of θ score or in direct way, but not being able to determine the solution of root of complex equation.
	Flexibility	Being able to input the complex equation, but still wrong in determining the score of x and y. Focused on a particular way.	Some students work directly without adhering the complex equations in another form.
	Originality	Solving the problem in his own way without having to be in line with the routine. The ways to sketch is nearly correct.	Has completed the required data, eventhough the result is incorrect,
	Elaboration	Not being to provide detailed procedures.	Some steps are not done

TABLE 3.
PROFILE OF STUDENT CREATIVE THINKING ABILITY ON MEDIUM LEVEL ACADEMIC

Level of Academic Ability		Medium	
Gender		Male	Female
Indicators of Creative Thinking Ability	Fluency	Some students do not find a solution, otherwise, they find the score of the square root of complex numbers.	Some of the answers are still incorrect in terms of interpreting the score of a graph.
	Flexibility	They try another way but result is incorrect.	Have already substituted the score of x and y to the form of the equation but it is still incorrect.
	Originality	Incorect to determine the θ score for z_2. There are also students who use the z^nformula.	There are relatively the same answers to the answer of the other student.
	Elaboration	Have not performed detail procedures, but directly input the score into the equation.	The final result is correct but have not worked on detailed procedures.

TABLE 4.
PROFILE OF STUDENT CREATIVE THINKING ABILITY ON LOW LEVEL ACADEMIC

Level of Academic Ability		Low	
Gender		Male	Female
Indicators of Creative Thinking Ability	Fluency	Some students are still incorrect in determining the score of r and θ. They have not found the solution the roots, but they find the score of the square root.	Has limited idea and therefore no willingness to be creative.
	Flexibility	Have not been able to determine the score of x and y.	Did not try the other ways to solve the problem.
	Originality	Some students tried to find the z^n, and sketch the graph.	Cannot sketch the graph due to the z^n score of the roots have not yet been obtained.
	Elaboration	There is an effort to solve the problems but in different concept.	There is no correct answer.

Source: Processed Data Researchers

To provide detail descriptions of the results of the student's answers at the academic level and gender, this study presents the following samples snippet of the interview with the representatives of the male students of high academic level:

P : What do you do first to complete the solution $z^3 = 3 + \sqrt{6i}$?

M1 : First, sought the quadrant score of r and its position.

P : What is the relationship with the quadrant?

M1 : Because it is associated with the determination of θ to find solutions to the complex roots.

P : But the final result is still incorrect, how come?

M1 : Ooo that was because of less careful in completing the calculation operation.

P : What is the difference with the question no 2?

M1 : I forgot that complex numbers could be written in the form of $z = x + iy$

P : Then, if the equation was $z^2 + z + 1 = 0$, What would you do?

M1 : I would use the ABC formula to find x and y, but I forgot to substitute it into the equation.

M1 statements showed that in the indicator of fluency and flexibility, male student representatives had been able to provide some ideas and solve problems with the correct answer in various ways. Although using different ways, there were still errors due to inadvertence. Based on the notion of [17], the male students representatives were in the levels of recall, basic, critical, and creative thinking. To check the students' achievement on the next indicator, the researchers clarified the students' understanding on the following items.

P : How did you determine the root of the degree 5 from $\frac{2(1+i\sqrt{3})}{(1-i)^2}$ and its interpretation of geometry?

M1 : First, I determined the score of r and θ, afterwards I checked the position of the quadrant, then I used D'Movre formula to solve the complex equation roots. Then I drew geometric interpretation.

P : Well, if so, what is the most important think to sketch geometry, what do you determine first?

M1 : That's the problem, I hope I was correct to determine the quadrant.

The above M1 statements indicated that in terms of procedures the student had understood, but there was a doubt in determining the quadrant position. This will obviously affect the determination of the roots of complex equations results in the sketch drawing. Further exploration was on a sample of female student's answer in the category of high academic level. Question number two was, determine the numbers of $z = x + iy$ from the equation of $z^2 + z + 1 = 0$, as follow.

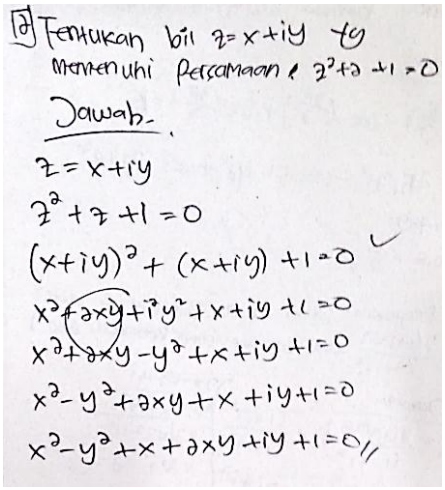

Fig. 1. *A sample of female student's answer in the category of high academic level*

P : How was your analysis so that you came to those answers
M2 : I immediately did the equation by factoring.
P : What made you think to use factoring?
M2 : Simply because of the square root, so I just did factoring.

The results of the M2's sample answer and dialogue demonstrated that female student proned to get over the questions and lack of depth analysis to determine the final result. Moreover, they only saw the question without considering other posible solutions of the correct answer. As the result, they became less careful and proned to strive to only one way of solving the question. Further exploration was administrated to the male and female students in the moderate category in the indicator of fluency and flexibility. It obtained that the students' answers were relatively the same, confused in determining the position of the quadrant and looking for r score and hesitate in determining the difference between the roots and cube roots of complex numbers. In contrast, in low academic level, both male and female students in fluency indicator still had problems and in flexibility indicator, they had not yet been succed, and they had not tried other ways.

4 DISCUSSION

The data of test and interviews demonstrate that students are generally able to give ideas, however, they have not been able to execute the ideas. Consequently, they solve problems limited only in a certain way. In that sense, they have not been able to create many ways. Besides, in terms of originality, most of students are able to solve the problem in their own way. This indicates a good character and therefore it should be basis for training and evoking creative idea. Based on the academic level and gender, this study obtained information about male students as follows. First, for the students who are at high and moderate academic level in fluency indicator have been able to provide a lot of ideas and solve problems. However, some of them have not answered correctly the questions because they are less scrupulous in terms of constructing the solutions and arithmetic operations. Besides, at low academic level, some of students are able to give a lot of ideas and try to address the problem, but they have not answered correctly the questions because of lack of understanding. This finding is accentuated by the findings of [27] showing that students have diverse backgrounds and abilities. Therefore, they have different potencies in the mind, imagination, fantasy and performance. Consequently, the students have a different level of creative thinking. This reflects a variation in terms of creative thinking. Second, in high, moderate and low academic level in flexibility indicator, the students are capable of solving the problem in various ways. This is indicated by the fact that some of the students are able to complete the data or information required to solve the problem. Nevertheless, the final result still has an error. Furthermore, in originality indicator, most of the students by their own way at all academic levels have been able to address the problems, although some students in low academic level still have incorrect answers. In addition, in elaboration indicator, the students of high academic level have been able to cope the problems using detailed procedures even though the result is still incorrect, whereas in moderate academic level, the students have tried to solve the problems, although it is not in detail, while in low academic level, the students have not yet been able to solve the problems in detail. This finding is accentuated by the view of [29] stating that there are some important points relating to creative thinking, that is, finding a new solution adhering the aspects of fluency, flexibility, originality, and elaboration. In other words, the process of creative thinking requires interwoven certain stages. For female students, the results of data analysis from tests and interviews depict the following information: First, in high and moderate academic level, the students have been able to comply the fluency indicator, being able to make a sketch of graph interpretation although some answers are still incorrect. In low academic level, the students have not been able to provide a lot of ideas because of limited understanding. This finding is consistent with the opinions of [24] stating that problem solving should be given start from mathematics subject at school. This is to bold students' cognitive construct so that they are familiar in solving mathematical problems. In addition, creative thinking needs to get used to skill and critical thinking [1]. Second, in high academic level in flexibility indicator, some students jump to solve the problems without considering the complex equations in another form. Furthemore, in moderate academic level, some students have tried to investigate the problems, although they are not completed yet. Besides, in low academic level, the students have not tried any other way. In fact, the students are not used to study hard. This is suggested by [8] that the students of low academic level should be train with various activities continuously, their learning ability and creative thinking are predicted to increase. Thus, the low academic level students which are often associated with failure in learning will not happen [20]. Third, in high academic level in originality indicator, most of the students have been able to complete the task in their own way. Furthermore, in moderate academic level, the students have relatively the same answer with their friends. Besides, in low academic level, the students have not solved the problems correctly. In additon, in elaboration indicator, the students of high academic level have already tried to solve the problems using detailed procedures, although the answers are still incorrect. Moreover, in low academic level, the students have not tried to find the expected solution. This finding is supported by empirical grounds, [12]; [25], show that there is a relationship between the gender and mathematics. Furthermore, in other study, there is evidence that gender differencies in mathematics achievement in the contexts of secondary level and beyond, male students reach a higher level than female students [11]; [31].

5 CONCLUSION

This study recapitulates that, based on gender, there is a difference in terms of students' creative thinking in solving the problem of mathematical square root of a complex equation. In all academic levels (high, moderate and low) on mathematical creative thinking skills, the students are able to solve the problem in their own way, however, they have not been able to solve the problem using detail procedures.

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