Neuroscience study: analysis of mathematical creative thinking ability levels in terms of gender differences in vocational high school students

N Adiastuty¹, Sumarni¹, M Riyadi¹, A Nisa¹, Waluya²

¹Universitas Kuningan, Kuningan, Indonesia
²Universitas Negeri Semarang, Semarang, Indonesia

Abstract. This study aims to determine the mathematical creative thinking abilities Level in the high mathematical creative thinking disposition category for each gender difference. This research is qualitative research using a qualitative descriptive method conducted at SMK Pertiwi Kuningan. This study describes mathematical creative thinking abilities of mathematics learning by collecting descriptive data obtained from the classification dispositions of mathematical creative thinking categories, creative thinking abilities test questions, and valid and reliable interviews. The research subjects chosen were four students from 57 students. The research subjects were two male students and two female students who had creative abilities, and the highest test scores were in the high mathematical creative thinking disposition category. Data analysis was performed with the stages of data collection, reduction, data display, and conclusion drawing. The results showed that male and female students in the high mathematical creative thinking disposition category have creative abilities that fulfill the aspects of flexibility, fluency, and elaboration. Flexibility and fluency aspects have an average score with very good criteria. Then, there are differences in the elaboration aspect, where the average score of female and male students are 3.9 and 3.4, respectively. It shows that the difference is not significant, namely 0.5, which indicates that female students are better at the elaboration aspect. Even so, male students also fulfill the elaboration aspect, wherein the very good criteria both. However, male and female students did not satisfy the originality aspect. The creative ability can be reached by having a high mathematical creative thinking disposition. Therefore, the teacher must be able to instill a high mathematical creative thinking disposition in mathematics learning. The high mathematical creative thinking disposition makes students flexible, fluent, and thorough in solving mathematical problems.

1. Introduction
Most of the nations in the world include Indonesia nation are in the process of improving the quality of education. It believes that the key to a nation's future to be decided by the existence of a quality education system [1]– [4]. Education is currently one of the vehicles to prepare and develop human resources who are ready to face and keep pace with advances in science and technology through the learning process [5]. Quality resources are the principal so that a country can compete in the era of globalization such that is full of challenges [6].

The challenges of the current globalization era require humans to be able to solve problems, both on a small and large scale, including learning mathematics [3]. The challenge of students in learning mathematics is that they must be able to solve complex problems or problems that are not routine. Therefore, creative thinking in learning mathematics is needed to solve complex and various problems.
[7]. The development of creative thinking skills has now become one of the focuses of learning, including learning mathematics. Students are expected to have logical, analytical, systematic, critical and creative abilities, and have the ability to work together [8]. According to [9] that creativity is a complex multidimensional psychological construction that is involved in fulfilling human potential to produce, pay attention to, and appreciate the beauty, excellence, and skilled performance in all areas of life, nature, art, science, or everyday experience.

However, the results of a survey by the international institute Program for International Students Assessment (PISA) in 2018 where Indonesia was ranked 72 out of 78 countries with a total score of 379 in mathematics. In addition, the results of the 2015 Trends in International Mathematics and Science Study (TIMSS) show the same thing that Indonesia in terms of students' mathematical ability is still low, ranking 44 out of 49 countries with a total score of 397 [10]. According to [11], the results of the TIMSS and PISA evaluation also show the low level of creativity of students in mathematics because the questions being tested are contextual problems, where it requires reasoning, argumentation, and creativity in its completion.

The low ability of mathematical creative thinking results in students feeling less understanding when they encounter math problems that are difficult to solve, so they tend to avoid them [12]. Mathematics among students has been labeled negatively as a difficult subject, scary, and boring [13]. It shows that the low ability of students to think creatively in mathematics creates a negative view of learning mathematics. The students' negative perceptions of mathematics raise a dislike for learning mathematics [14]. So even though the students' intelligence is at the normal level, if they have a negative attitude towards learning mathematics, are high anxiety, and are not sure of their abilities then their mathematics achievement is also low [15].

Mathematical creative thinking skills and perceptions that build students’ thinking towards mathematics learning, namely to measure it, can be viewed from gender factors and students' mathematical creative thinking dispositions [16], [17]. Research conducted by [18] shows that gender affects the achievement of students' creative thinking abilities. Many complex variables include biological, psychological, and environmental variable is to expressed to contribute to gender differences in solving mathematical problems in certain areas. According to [19], the use of strategies found different patterns in solving math problems between male and female learners related to cognitive abilities, along with psychological characteristics and mediated by experience and education. However, the results of several studies suggest that the gender factor is inconsistent, some finding that men generally outperform women on math tasks [20]. Also, [21] suggested that there is a very little gender difference in mathematics performance on a test. Some show different measures of gender differences concerning types of math tasks [22].

In addition to gender, students' mathematical creative thinking skills towards mathematics learning also can be measured by mathematical creative thinking dispositions. The increase in the strong desire of students to hone their mathematical creative thinking skills which are called the mathematical creative thinking disposition will also increase the mathematical creative thinking ability [23], [24]. Also, students who have high mathematical creative thinking dispositions will form individuals who are tough, resilient, responsible, have high achievement motives, and help students achieve their best results [25].

Based on the results of a preliminary study by giving mathematical creative thinking skills test questions, to class X students at SMK Pertiwi Kuningan showed the students' low mathematical creative thinking skills. This can be seen from the average results of the test assessment using the Two-Variable Linear Equation System material. Female students only reached 24.58 while male students had an average of 36.18. This is due to a lack of understanding of the material. It can also be seen that students do not have a mathematical creative thinking disposition or a strong desire to hone their mathematical creative thinking skills. This can be seen in the answers of students who only answered test questions with one answer and one method. Besides, this also shows that there are various perceptions of students towards learning mathematics that need to be known to achieve the success of learning mathematics. According to [26] that gender differences can be seen from the
results of students' completion, where this study shows male participants use more flexible solutions than women. Whereas in concluding female students are more careful and thorough and competent in communicating the ideas they get.

The results of the preliminary studies above are certainly not by the stated expectations of educational success. Some of the views, thoughts, and assumptions developed in the description above indicate a gap between the real conditions and the expectations in the fields. So, the purpose of this study is to determine the mathematical creative thinking ability of students in the high level mathematical creative thinking disposition category for each gender difference.

2. Methodology
This research uses descriptive qualitative research. Based on the data from the study results and the suitability of the research objectives, this study used a qualitative descriptive method. This research was conducted at the SMK Pertiwi Kuningan school in Kuningan City, West Java Province. Taking the subject in this study using a purposive sampling technique. The research subjects were selected by considering gender and having a high ability to learn mathematics, the consideration based on the focus of this study, namely analyzing creative students with the highest test score in the high mathematical creative thinking disposition category for each gender difference. So that of all class X students of the 2019/2020 school year as a population, the teacher recommends two classes totaling 57 students, namely class X TKJ 1 (Computer and Network Engineering) totaling 29 specifically for male students and class X PBK 1 (Banking) totaling 28 specifically for female students.

In this study, the two classes sampled received the same treatment (learning method) as the same mathematics teacher. The material used in this study is the matrix. The matrix has been learned by the classes both. Amount of 57 students fill a mathematical creative thinking disposition questionnaire, then they do a mathematical creative thinking ability test, and finally an interview. The data was collected by the researcher directly so that the first instrument in this study was the researcher himself. Then it's assisted by the instrument of disposition categorizing of mathematical creative thinking, questionnaires on students' perceptions of learning mathematics, tests of mathematical creative thinking abilities, and valid and reliable interviews.

The validity of the data was done by triangulating techniques and sources. In the first step, the researcher collected data using all the instruments made, where the data in this study were from questionnaires, tests, and interviews. So the research was carried out through online media online (in the network). Researchers used WhatsApp in conducting the research. Since lots of data, the researchers reduced the data which focused on student data in the high mathematical creative thinking disposition category whose creative abilities score and the highest test score. After being reduced, the data were presented in descriptive form for further verification or decision making.

By the focus of this study, so that of the 29 male students who had creative abilities with the highest test scores in the high mathematical creative thinking disposition category, they were subjects IS6 and TH13. For female students, 2 out of 28 students were selected, who have creative abilities with the highest test score in the high mathematical creative thinking disposition category, namely GY5 and HM6 subjects.

3. Result and Discussion
3.1 Mathematical Creative Thinking Ability in High Mathematical Creative Thinking Disposition Category for each Gender
Analysis of mathematical creative thinking skills was obtained by tests and interviews on research subjects. Based on the data analysis, it found that the research subjects, in two male students, the subject IS6 got a score of 3.70 and the subject TH13 got a score of 3.02 in the creative ability level, respectively. In two female students, the subject GY5 got a score of 3.70 and the subject HM6 got a score of 3.57 in the level of creative ability, respectively. This research subject was also included in the high mathematical creative thinking disposition category, with the high category. That can make
students have creative abilities in solving math problems by fulfilling three aspects of mathematical creative thinking skills, namely fluency, flexibility, and elaboration.

According to Guilford and Runco that another important cognitive dimension of creativity is the production of distinct ideas, usually considered more important for creative performance than general intelligence. That is a type of thinking that aims at a plurality of answers, both in quantitative terms (fluency) and at a qualitative level (flexibility, originality, and elaboration) [27]–[29]. That is consistent with the results of [23] that students with positive mathematical creative thinking dispositions have high abilities in mathematics. Generally, weak creative performance is associated with low intelligence levels as well [29]. It shows that male and female students with high mathematical creative thinking dispositions can also achieve high abilities in creative thinking, and the creative students are students with high intelligence.

The results of this study on the aspects of fluency and flexibility, male students achieved an average score of 4 as well as female students achieving a score of 4 by meeting very good criteria. Moreover, with the high mathematical creative thinking disposition of male and female students, it also shows that students often try to try several different strategies to get the best solution in solving math problems and feel confident when taking the initiative to propose various alternative solutions when there are problems. Mathematics. Research finding by [24] also point toward that students who have a mathematical creative thinking disposition will be flexible in thinking and responding, respecting fantasy, initiative, self-confidence and independence.

In the elaboration aspect, there are differences between male and female students, in which the average female student is 3.9 and male students are 3.4, both of which are very good criteria. That shows that the difference is not too significant, namely 0.5 in the elaboration aspect. There is a very small gender difference in mathematics performance on a test [21]. Although male students reported meticulous work on complicated mathematical tasks, the neurons that carry messages between the two hemispheres of the female brain are larger. This explains that women use both sides of their brain for language. Besides, the corpus callosum (CC), which is a collection of nerves that connects the left-right female brain is larger where women can maximize both hemispheres of the brain, so that it can enable better communication in the hemispheres [30]. So that females are better in the aspect of elaboration, although not too significant.

But on the whole aspect of mathematical creative thinking skills in terms of gender differences, it can be concluded that there is no significant difference in the average of it. Both male and female students fulfill three aspects, namely fluency with very good criteria, flexibility with very good criteria, and elaboration with very good criteria which are included in creative students. The results of several studies also state that gender factors are inconsistent in mathematics [20]. This is an insignificant difference because females currently receive the same education as males. Even now, more females are taking education because the number of female students is higher than the number of male students [31] so that females and males have the same opportunity in terms of having high abilities.

In addition to the above, it found that male and female students did not fulfill the originality aspect because the new methods that be used in solving problems were obtained from the teacher, not from their thoughts. As for one male student who produced a new way of thinking on his own, but was wrong in explaining the concept of the new way he used so that it did not fulfill the originality aspect. Students also stated that they often felt satisfied if they gave only one answer to each math problem using the same method that was taught by the teacher. This shows that male and female students have not been able to develop aspects of originality. Similarly, [32] found that students tend to say that finding unusual ways is made by students at a general level of thinking and looking for other ways is difficult compared to finding other answers. Also, [33] states that the order of difficulty levels in creative thinking is the aspect of originality/novelty, then flexibility and fluency.

So, with a high mathematical creative thinking disposition, male or female students can reach the level of creative ability. Meanwhile, there is no significant difference in the mathematical creative thinking abilities of male and female students when viewed from gender differences because men and
women have the same opportunities in education with each their ability. In terms of gender, there is a difference in whether or not the material is fast. In this case, male students in the high mathematical creative thinking disposition category are faster in receiving or absorbing material than female students. Moreover, female students are not always quick to absorb the material. But in terms of memory, female students are more vigorous in remembering the material they have learned than male students. It is consistent with [31] that the memory center (hippocampus) in the female brain is greater than that of men such that men forget more often than women.

Also, male and female students in the high mathematical creative thinking disposition category are highly optimizing themselves in accepting or absorbing mathematics learning. Their way of optimizing themselves is by focusing on paying attention to the teacher who is explaining, not often looking right or left during learning, choosing the front seat, discussing, helping friends who don't understand the material, working on any questions the teacher gives, often presenting in front of the class to explain the results of the discussion and always ask friends or teachers when they get into trouble. That is support by [24] which reveal that students who have a mathematical creative thinking disposition show broad curiosity and interest. Also, according to [23], the optimal and conducive process of teaching and learning mathematics can provide a positive attitude towards students' creative thinking dispositions.

Besides, in the aspect of understanding or understanding, male students mostly understood mathematics material. They stated that they only did not understand one different material, namely those who did not understand the limited material and did not understand when they encountered new material. Meanwhile, some female students said they did not understand one material, i.e. Two-Variable Linear Equation System, and some understood all the material. It can be concluded that male and female students in the high creative thinking disposition category mostly understand mathematics material, on average they only do not understand one material. It is also following [24] that students who have a mathematical creative thinking disposition have good emotional stability.

4. Conclusion

This study concludes that male and female students in the high mathematical creative thinking disposition category have creative abilities that fulfill the aspects of flexibility, fluency, and elaboration. Flexibility and fluency aspects have an average score of 4 with very good criteria. Meanwhile, there are differences in the elaboration aspect, where the average score of female and male students are 3.9 and 3.4, respectively. This shows that the difference is not significant, i.e. 0.5. It indicates that female students are better at the elaboration aspect. Even so, male students also fulfill the elaboration aspect, where both of them are in very good criteria. However, male and female students do not fulfill the originality aspect.

Suggestions based on the results of this study are male and female students in the high mathematical creative thinking disposition category, which they can increase the number of exercises that have aspects of originality. The ability to think mathematically in the originality aspect is still not fulfilled by male and female students. Therefore, teachers should pay more attention to the characteristics of students to adjust teaching methods to be able to improve students' abilities in aspects of originality. Teachers can instill mathematical creative thinking dispositions in mathematics learning, especially in male students, because they are less than female students in the high category. Teachers need to get used to giving questions with non-routine types so that students can hone their mathematical creative thinking skills.

The students' mathematical creative ability could be achieved by having a high mathematical creative thinking disposition. Therefore, the teacher must be able to instill a high mathematical creative thinking disposition in mathematics learning. The high mathematical creative thinking disposition makes students flexible, fluent, and thorough in solving mathematical problems.

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