Neuroscience study: Gender and mathematical creative thinking skills in vocational high school students

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Abstract. The main idea in this article is looking at the creative thinking patterns in mathematics learning viewed from gender on vocational high school students. Creative thinking skills are cognitive processes, and cognitive processes are inseparable from how the brain processes work. To see the ability to think creatively, we have to see how the process of creative thinking happens. This is a neuroscience study in mathematics with a quasi-experimental design. We tried to describe the relationship among neuroscience, mathematics creative thinking skills, and gender. We involved 30 male students (automotive major) and 30 female students (accounting major) from the 12th-grade of Islamic Center Vocational High School of Cirebon, West Java, Indonesia. Statistics test used was independent sample t-test to see about mean differences of males and female group. There are three indicators about mathematical creative thinking used are fluency, flexibility and novelty. Finally, we found that male students and female students have their own structure of the brain. Female students have a higher ability of mathematical creative thinking skills than male students in Islamic Centre Cirebon, West Java, Indonesia.

1. Introduction

Creative thinking is something that students need to solve problems and find alternative solutions to the problems. Students' thinking process in vocational high school may differ from the senior high school, because students in vocational high schools are prepared to be skilled and ready to work. Thus, the ability to think creatively is an ability needed by students. Measurement of the creative thinking process is difficult to do, but creativity can be assessed by looking at the creative product resulted from a project. However, before arriving to a product, the students have to pass four levels of creative thinking [1] including the preparation stage, incubation stage, illumination stage, and verification stage. And finally, it ends with the revision stage. These five stages will be used as a reference for observing students' creative thinking process.

In mathematics learning, familiarizing students with the process of creative thinking through continuous practice is one of the efforts to improve mathematical creative thinking abilities. The weakness experienced by the Indonesian 2013 curriculum, especially in mathematics today, is not balance between the orientation of learning processes and learning outcomes. The problems in the final examination on the last grades is only result-oriented, not pay attention to the learning process. The characteristics of the revised 2013 curriculum emphasize that students must have high order
thinking skills, one of which is the ability to think creatively. Meanwhile, students are still required to pursue the target minimum criteria by all means, but they are not given space to express their ideas and thought patterns. Studying and observing how students’ thought processes have not received special attention in classroom. We are curious on a question, is there a difference of the thinking process between the male-dominant class and the female-dominant class.

Mathematical creative thinking skills and creative activities cannot be separated from the working process of the brain. Neuroscience research is a trend in mathematics education. It can be a solution for more advanced mathematical thinking because it provides a new perspective on how to manage and optimize student’s brain as a control in the learning process. Why gender is important in research on vocational high school? This is because there are some majors in vocational which have a unique characteristics of majority, such as the department of automotive or mechanical motorcycle is dominated with male students. But in the other major class, it is dominated by female students such as department of administration or secretary. Therefore, this article will discuss how the creative thinking skills in vocational high school viewed from gender differences. Gender is a neuroscience-related issues that we as researchers must consider the structure of the brain and brain work system and how to enter the memory process, because male and female have different brain structures.

Dwijanto stated that mathematical creative thinking is the ability to provide a variety of answers based on information provided with an emphasis on diversity in number and suitability in solving mathematical problems [2]. The ability to think creatively will grow well if students learn with their own desires, are given the confidence to think, and dare to convey new ideas. De Bono stated that there are four levels of development of creative thinking skills, namely thinking awareness, thinking observation, thinking strategies and thinking reflection, while Silver stated that indicators of creative thinking consist of indicators of fluency, flexibility and novelty [2].

There are several tests to test one's creativity. Giving task to choose to use some alternative in answering the question are under the classification of thought diverging, this is a task are widely used to assess creativity. Tasks like that assess aspects of creative thinking single or double [3]. This kind of thinking has the potential to get a number of ideas or solutions. This is different from the task of converging thinking where there is only one solution to be achieved. However, a novelty factor influencing fundamentally, a shift of perspective or overcome the improvement in functional which then allows one to solve the problem [4]. The task of converging thinking is used to assess specific aspects of creative cognition, such as analytical insight into problem solving [3].

Creativity can be seen in completing various tasks, have a different mindset, and then collectively assessed for getting one's creative ability index. One of the example to test the divergent thinking skills is through the Torrance Test of Creative Thinking (TTCT). Furthermore, assessing creativity could be done through the Consensual Assessment Technique (CAT), in which a product is produced and then evaluated by experts in terms of the level of creativity is generated. These four methodologies (assigning different tasks, converging tasks, divergent tests, and CAT) are the most widely used assessment tools to measure the ability or potential of creativity. CAT reflects the terminology used when referring to the six Ps of creativity, namely process, people, product, place, persuasion and potential, or the theoretical approach adopted when investigating creativity [5].

2. Method
The method used was based on the quantitative research to determine the differences in the abilities of creative thinking viewed from gender. The results were compared with some literature review. Quantitative study with a quasi-experimental design was used to test the sample of the population. The population was students from Islamic Centre Vocational High School in 12th grade, with 30 male students from automotive major and 30 female students from accounting major. Statistics test used was independent sample t-test to see the mean differences of male and female class. There were three indicators about mathematical creative thinking used. They were fluency, flexibility, and novelty.

In this article, we studied the relationship about neuroscience and the process of mathematical creative thinking and gender viewed from empirical studies from the others researchers. The function
of literature review are: (a) identifying on a subject or topic article; (b) determine the trends of research and the scope of research; (c) incorporating empirical findings from several articles as supporting theories of practice-based practice; (d) produce a framework of thought and then get a new theory; (e) do further research by identifying the topic or question in the article [6].

3. Results and discussion

Creative thinking skills are cognitive processes, and cognitive processes are inseparable from how the brain processes work. To see the ability to think creatively we must see how the process of creative thinking. So, we must observe each stage or process of creative thinking so that it is expected that when each stage is observed we will know at what stage the deficiencies faced by students in vocational high schools.

From the sample in Islamic Centre School in Cirebon (30 male students in automotive department and 30 female students in accounting department), the test results shows that the data of ability of mathematics creative problems was normally distributed. It allowed the data to be analyzed using statistical independent sample t-test at \( \alpha = 0.05 \) significance. The null hypothesis for the independent sample t test is \( \mu_{\text{males}} = \mu_{\text{females}} \). We got \( t = 4.716 \) compared to \( t \) table (df 58) = 1.671, then the t-test was greater than \( t \) table. Thus, we have to reject the null hypothesis. The result is the abilities of mathematical creative thinking viewed from males and females is different. Females student has higher abilities of mathematical creative thinking skills than male students.

We finally also can show the recapitulation of creative thinking skills analysis of class 1 (male students) and class 2 (female students) in Figure 1.

![Figure 1. The mean of male (1) and female (2) mathematical creative thinking](image)

From Figure 1, we can see that the mean of a class who dominated by female student has higher creative thinking abilities 6.00 than a male-dominated class who only has an average of 4.2. Let’s compare this results with the others neuroscience research about gender and creative thinking skills.

3.1 Neuroscience in mathematics creative thinking process

Neuroscience research is a trend in mathematics education. it can be solution for more advanced mathematical thinking, because Mathematics is a science of patterns and relationships, and numbers and arithmetic are often even avoided when mathematical thinking occurs at a higher level. Letters are used that stand for a general number, and arithmetical operations cannot and do not longer need to be conducted [7].

We can assess intermediary factors, such as the characteristics of the personality, perception, self-efficacy and index of achievement, and all that is associated with creativity Creative Achievement Questionnaire (CAQ). The important issue that emerged was how the methods that have been selected and will be applied in the methodology (because of the variability in the provision of duty and the response size) makes it difficult to connect and integrate the findings of several studies [8]. For example, in the case of alternative use assignments, some studies find differences in creativity based
on their fluency in measuring (the number of ideas generated), while others find differences in the size of originality (the uniqueness of ideas generated). However, even when significant findings are specific to the size of the response to certain authors tend shortly generalization and shortly discuss returning the implications in terms of creativity as a whole. Once heterogeneous in the methodology used finally came the conclusions that are not specific and generic. And this is what causes insignificance with what is happening on the ground.

Royer say that neuroscience in education experience could conceivably help to better understanding the relationship between biological brain development and to developing the human capacity especially for mathematical cognition. Neuroscience will not and should not eliminate behavioral and psychometric studies that can provide independent insight facilitating the development of new experimental paradigms for neuroimaging studies. Neuroscience findings have not made it directly into the mathematics classroom at present. However, this should not hinder research and we would like to investigators not only to continue but also to extend their study of educational neuroscience. Neuroscience research today is setting the scene for future developments in mathematics education [9].

The others creative research is about the creativity structure issues, the present study established a relation between the developmental and social psychology of creativity, including the instruction provided by teachers and how can make all students are systematically exposed. More research such as this is needed in creativity model building and testing, as well as a broader outlook on developmental issues inherent in the structure of creativity and how it changes. Gender and age factors were the only variables measured. And from this research, it can provide opportunities for how to change the individual creative behavior items into single lessons, projects or educational programs aimed at the EAS creativity development [10].

The study of Spüler fits into a trend of research wherein attempts are made to use “brain computer interfaces” that are expected to allow for a more direct and implicit monitoring of learners’ states like cognitive workload by means of measuring specific neural correlates. Mathematics students should be kept in an optimal range of cognitive workload to ensure that they are operating within their “zone of proximal development”, and, therefore, it would be desirable to adapt the difficulty of (computer-based) training content to the learner’s individual competencies [7].

3.2 Difference in thinking between men and women
Comparison of the process of thinking between men and women, the nature is indeed different, a book that explains the differences between men and women, namely men are from Venus and women are from Mars. Not only physically, brain structure and ways of thinking between genders also have differences. That men and women have evolved physically but still carry the habits of ancient men and women. As a result, his body and brain developed according to the habits of this ancient era. Over millions of years, the brain structures of men and women continue to change in their respective ways. We arrived in this modern era, where it turns out that men and women are different in processing information that enters their brains. The way of thinking is different. The sense would be a single thing differently. Perceptions, priorities and behavior also differ [11].

The issue in mathematics education based on gender differences in cognition is carried out several studies in research. particularly with respect to mathematical performance, although boys and girls were same ability in general intelligence, but boys performed better on mathematical reasoning, and girls performed better on tasks of verbal comprehension [12]. Some empirical research has indeed confirmed that differences in general intelligence are not modulated by gender [13]. The idea that there is a gender-specific advantage which is domain general. Female is good in verbal and spatial or male is good in quantitative, although has not been clearly elaborated [3].

Some evidences about exploring gender differences in cognition and brain function show that gender does not differ in terms of global or specific intellectual abilities but may do so in cognitive strategies, functional task sets, or cognitive styles. Based on this, we can do further exploration in the field of gender differences in creativity [3].
In addition, it discusses the differences in brain structure between men and women, how science determines that men and women are truly different, both physically and spiritually. They are not the same. We have investigated research conducted by a leading paleontologist, ethnomethodology, psychologist, biologist and neurologist. The differences in the brains of women and men are now increasingly clear, free from all speculation, prejudice or reasonable doubt. We know that there are two hormones that play a role in men and women. In the male body there is the hormone testosterone which plays a role in creating an element of their masculinity. While estrogen plays a role in developing feminine traits. Habits, hormones, and brain structures cause these differences between men and women [14].

Assessing the function of the woman brain explained that the structure of the brain differs to men in way of thinking, way of looking at things, way of communicating, and so forth. This different way of thinking also influences students' creative thinking processes [15]. Comparison in terms of creativity has also been investigated by Munandar of Indonesian high school students who found that female students' creativity tended to be higher than male students with a ratio of 58% versus 42%. The same results were found in Aziz's (2006) study of 82 students, and it was found that students with high levels of creativity were found to be more girls (53%) than boys (47%) [16].

Different research on creativity to explain that there is a relationship between gender differences in men and women with the level of creativity of the students both in quantity and quality [17]. The results of their analysis of several research journals from 1958-1998 found differences in ability both in indicators of fluency, flexibility, originality, and elaboration. Students with female sex tend to be higher on indicators of fluency, originality, and elaboration. Men tend to be higher aspect of his flexibility, although the different is not too significant. Furthermore, male and female differences about thinking styles based on Sternberg's theory of the seven types of creative thinking styles have been investigated by Tafti & Babali [18]. The results showed that men's thinking styles are more legislative, liberal, and global, while women's thinking styles are more executive, juridical, conservative, and local.

The preliminary hypothesis that men will report being better at using orientation strategies and in overall wayfinding competence than will women, we conducted an overall MANOVA for gender differences in all primary study variables. And from statistics, the main effect of gender was significant, Wilks' $\lambda = 0.78$, $F(6445) = 20.70$, $p < 0.001$, $\eta^2 = 0.22$. Univariate analyses indicated that gender differences were present for both measures and in the expected direction with $F(1450) = 29.82$, $p < 0.001$, $\eta^2 = 0.062$ for orientation strategies; $F(1450) = 29.96$, $p < 0.001$, $\eta^2 = 0.062$ for overall way finding competence. Men used orientation strategies more often than women, and men reported a higher level of overall wayfinding competence than women. Nevertheless, ad hoc tests found that the correlation coefficients between feminine cognitive characteristics and overall wayfinding competence were not statistically different in ($r = 0.11$) than in women ($r = 0.09$). Also, note that gender typed characteristics measures accounted for a smaller amount of variance for women than for men. For both men and women, higher masculine cognitive characteristics predicted better wayfinding competence and higher feminine personality characteristics predicted poorer wayfinding competence. However, higher endorsement of feminine cognitive characteristics predicted better wayfinding competence for men but not for women [19].

From a mathematics course with all member in women only, we get information about course effectively to examine from a global perspective the experiences of women with mathematics. Students learned that not all mathematicians are white males standing in front of a blackboard. They learn that white women and all people of color face discrimination in the world of academic mathematics. But they also learn that women were the earliest mathematicians; they learn that mathematical ideas come from many cultures—not just from Western societies; and they come to realize that mathematics is something they successfully do every day of their lives. And finally this course is a first step toward changing students' perceptions of mathematics and making them aware of the sexism, racism and elitism in mathematics. I think the biggest thing I learned is that we can all do math but we need support and encouragement from others. I now know that there are no differences in
the genes of females which do not allow them to do math as well as other groups. It is provided that woman and men have a similar ability in mathematics [20].

We get a nice information in the end, sex may be one important factor influencing our behavior, but not only men and women differ. Every individual is different and should be accepted as such. [21] but hypothesis that women and men differ in their pursuit of careers in science, technology, engineering, and mathematics (STEM) owing to biological differences in mathematics aptitude. However, little evidence supports such claims. Some studies of children and adults (different age) show if gender; males and females differences in mathematics performance, research on 3-10 years old children's neural development, analyses girls and boys showed significant gender similarities in neural functioning, indicating that boys and girls engage the same neural system during mathematics development [22].

Dew and Galassi found that females score higher on math anxiety measures than males. females had a negative self-perception on capabilities and self-domain within themselves. Females tend to believe that they were less capable in mathematics, thus they had a lower self-confidence in any numerical task. The same studies also discussed that females believed that mathematics was better suited to males, thus would feel more anxious to perform the numerical task because of their own gender [23]. And the other research found similar math anxiety scores between man and woman. It is possible that the females' perceptions had been altered by positive learning experiences associated with math, which decreased their anxiety and increased the drive for achievement for both of gender, males and females [24]. The other test about Treatment and achievement in mathematics has No significant effect exists on treatment and gender, but, male has higher achievement mean score (x = 57.50) than female x = 54.13). Multimedia apparently provides positively influenced the academic on performance of students in mathematics [25].

4. Conclusion
The average ability to think creatively in vocational high school among female students is higher than that of male students, but studies on gender still have mixed results. In some cases, it is stated that gender differences do not affect the thinking process, but in other cases, gender variables are very influential on one's thinking ability, especially in mathematics. Neuroscience research in mathematics education is still rarely done, exploring further about brain function and working memory in order to optimize high-level abilities in the mathematical field, one of which is the ability to think creatively.

Learning and understanding about the differences between men and women in creative mathematical thinking processes, we know that basically the two are having different brain structures and abilities. The scope of research in vocational high school is still very little, so it is expected that with more and more research in vocational high school it will get a solution of the problems faced by the Indonesian nation that can reduce the number of unemployed graduates of vocational high school graduates and hopefully the quality of graduates is more skilled and creative and ready to work.

Acknowledgement
This article was supported by the Department of Mathematics Education of Universitas Kuningan and thanks for my lecturer in my doctoral programme in Universitas Negeri Semarang.

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