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Mathematical Communication Ability of Junior High School Students in Solving Mathematics Problems

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Abstract

This study aims to describe profile of junior high school students' mathematical communication ability in solving mathematics problem based on cognitive style and gender. Cognitive styles discussed in the study were field independent (FI) and field dependent (FD). This study is an explorative research with a qualitative approach. The participants of the study were four students in eighth grade, two men and two women. The data were gathered from students' written work and interview. To ensure the credibility of data, triangulation method was employed. The data analysis done qualitatively using three stages of data reduction, data display, and drawing conclusions. Data analysis done based on students' mathematical communication ability including: (1) the understanding of the math problem, (2) the using of the mathematics language, (3) the using of mathematics representations, (4) the using of mathematics skills, and (5) the oral explanation of the process in problem solving. Results of this study show that the female students performed better in using mathematics language and explaining orally. Also, the FI-cognitive style students more detail than FD-students to explain making mathematics model.

Keywords: *Mathematical communication, cognitive style, gender.*

1. Introduction

Mathematics is a compulsory subject for students in every level of education. In the National Standard of Education of Indonesia, it is mentioned that the aim of school mathematics is to support the students' development mastery in problem solving and communicating ideas using different representations, e.g. symbol, table, diagram and graph [1]. Besides that, solve challenging problems and communicate ideas are two aspects that influence students' development of mathematical thinking, together with the skills in investigating pattern, making conjectures and drawing a logical-based conclusion [2].

The importance of problem solving and communication also stated in Educational Standard Process in United States. There are five core activities recommended by National Council of Teachers of Mathematics (NCTM), i.e. problem solving, reasoning and proof, communication, connection and representation [3]. Furthermore, curriculum in Singapore consider problem solving as the main goal of learning mathematics through five intertwine components of concepts, skills, process, attitude and meta-cognitive [4]. In the revision of the curriculum, reasoning, communication and connection are added.

Problem solving and communication are closely related skills. The communication skills needed when students' want to communicate the processes or results of solving a

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problem. Even though a student's thinking might be mathematically correct, lack ability of communicate it will hinder others to see the point. Also, a good communication skill will enable students to effectively use data to solve a problem. Therefore, mathematics classroom should be design to provide the opportunities for students in communicate ideas especially solving mathematical problems [5]. A study in Japan found that students' success in solving mathematical problems highly supported by teachers who concern on the improvement of students' mathematical communication skills through various number of activities including group observation, manipulation and experiments [6].

Communication is an integral part of the curriculum to prepare the students to develop 21st century's challenges and competencies [4]. It can be used as supporting tools in mathematical transmission as well as foundation in learning mathematics [7]. Here, communication skills can be shown from students' competency to represent, listen, read, discuss and write mathematical ideas. Therefore, the students' communication skills can be observed from their explanation using mathematical language, including its representation – verbally and orally.

Despite of its importance, the training for communication skills tend to be dismissed or only receive minor attention in the classroom [5]. It is because, some people believe communication is a natural abilities and people born with it. However, the results of previous studies indicated students' mathematical communications were low [9]. This can be seen from the students' inability in translating the word problem in daily context into mathematical notation [8].

In fact, people abilities in transmit and receive mathematical ideas when solving problems are influenced by various factors, including cognitive styles and gender. Everyone has different characteristics in their cognitive structure when dealing with problems. It impacts how they think, argue and solve the problems. It usually called with cognitive styles, a consistent and resistant process happened in a person's cognitive [10]. In general, cognitive styles can be divided into Field Dependent (FD) and Field Independent (FI) [10].

People with FD cognitive style tend to review the problem globally and consider the context or background in which the problem lies. Meanwhile, the people with FI cognitive style tend to see the problem analytically and not consider the context. The FI people are capable to abstracting the elements of context or background. These differences lead to the difference in learning style and also how they solve and communicate mathematical problems. Therefore, to describe the students' communication skills comprehensively, the cognitive styles should be considered.

Besides the students' cognitive, the social concepts which distinguish the male and female – or usually called gender [11] needs to be acknowledged. Previous study figured out how gender influence students' learning outcome, attitudes and participation [12]. However, this concept can be biased as sometimes it is not really gender, but socio-economic background which contributes to differentiation of learning process and results. Looking at the polemic, this study aimed to provide new insight of whether or not gender impacts students' communication skills.

The present study aims to profiling students' mathematical communication skills based on their cognitive styles and gender differences. The communication skills will be evaluated from the following indicators performed by students in: (1) restating the problem using their own words, (2) using mathematical language to present mathematical ideas, (3) employing mathematical representation to present the ideas, (4) using mathematical skills to explain the ideas and (5) using mathematical skills to support the process of finding solutions [13], [14] & [15].

2. Method

This is a descriptive qualitative study aimed to digging out the actual reason behind a phenomenon, in this case the profile of communication skills of the junior high school

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students based on their cognitive styles and gender differences. The subjects were four students at eighth grade of junior high school, 2 males and 2 females each in FI and FD cognitive styles. Hence, there were 1 male FI, 1 male FD, 1 female FI and 1 female FD participated in the study. Four of them were having relatively equal mathematics basic knowledge.

To gather the data, the participants were asked to work on mathematics problems and followed an interview afterwards. The problems employed in this study was judged by experts for having a valid content, construct and language structure. The interview aimed to reveal more details on how students' solving the problem. To ensure the interview run as is intended, a guidance form was prepared. We only use one problem for each research session to ensure the students focused on the process.

Data triangulation was applied in this study to enhance the validity and credibility of data. Here, repeated data gathering by testing and interviewing the students were applied to examine the consistency of the results. The collected data were analyzed qualitatively using the Miles & Huberman method, following the steps of Data Reduction, Data Display and Drawing Conclusion [16].

3. Results and Discussion

The results of the study summarized in the following Figure 1. It provides the illustration of relation between mathematics communication and problem solving in every student. Figure 1 explains the processed from creating, reading and understanding problems; continued by creating and solving the mathematical model and followed by interpreting solution; based on students' cognitive styles and gender. In general, Figure 1 divided into three parts: left is the profile of communication based on the information given from the text, right is the profile of communication based on the information given from the picture/illustration and center is the steps of problem solving.

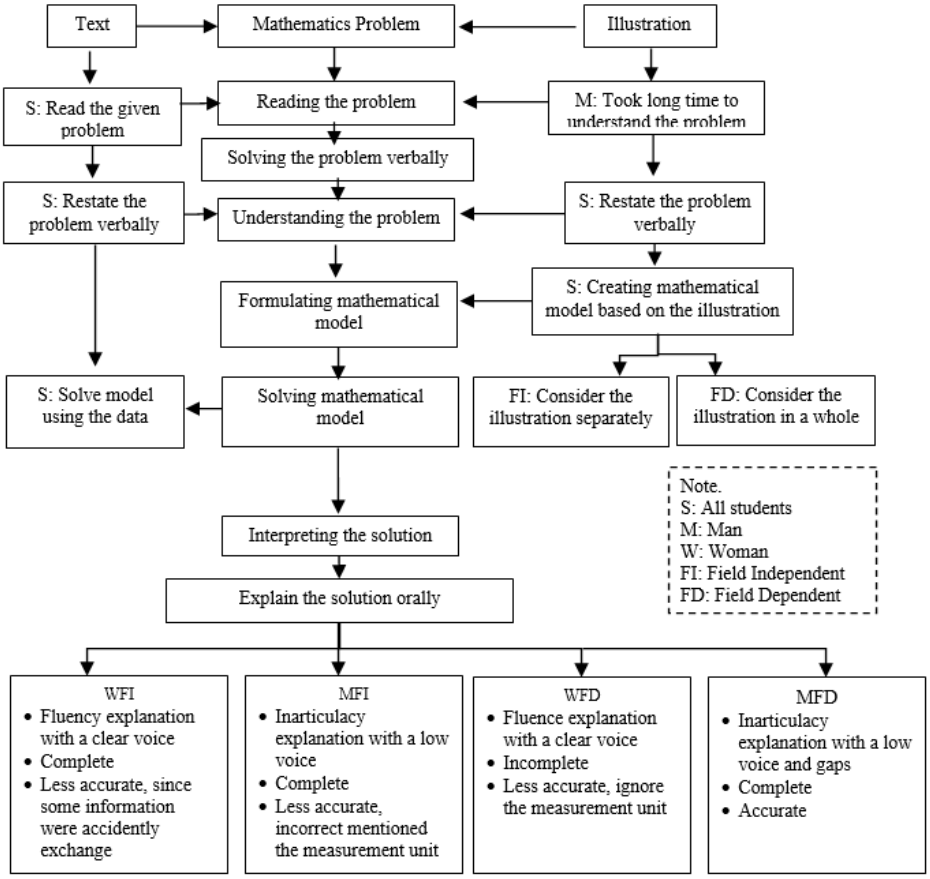

Figure 1. Communication Skills and Problem Solving

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Based on Figure 1, it can be seen that female students (code with W/Woman) tend to read the problem repeatedly, while the male students (code with M/Man) tend to observe the illustration. The result in line with the study of Van den Hauvel-Panhuizen that female students have a better competency in reading complex text [17]. In addition, it is stated that male students prefer to look at the picture instead of read the text, while female students choose to read the text and look at the picture occasionally. Meanwhile, in general, males are interested to objects, games and pictures since earlier age [25]. Hence, we used to hear that male is a visual human being. On the other hand, females are interested in expression of others that make them develop a better interpersonal and intrapersonal intelligences.

The FD and FI students were varied in creating the mathematical models. The FI observed the picture in detail while FD looked at the general picture. This is in line with the previous study that FI performed better in describe the solution compared to FD [18]. They also tend to be more details [10]. Therefore, the results of this study support the theory that cognitive styles influenced the students' point of view in working on the problem.

Another remarkable finding in this study is that every subject tried to understand the information after the problem given. They tried to distinguish the "known" and "unknown" parts of the problem based on the information on the text or picture. They also focus on the details of the numbers given in the problem, i.e. the size of certain shape. Besides that, the students were able to determine what is being asked in the problem. This is because, they repeatedly the problem before work on it. The finding in line with the study of Winarni that said the understanding of the problem increases as the students repeat to read the information [19].

In this study, all of the students merely wrote the information given in the text, not re-write the information resulted from their exploration from the picture. Therefore, it can be concluded that students encountered difficulties in writing the verbal language from the illustration given. This finding can be elaborated more to figure out how students communicate visual information verbally. It can also be connected to the students' cognitive development from Piaget.

In understanding the problem, the subjects identified the mathematical objects given on the problem. There are interrelated objects in the problem, e.g. square and rectangle. From the interview, it was found that the students with FD cognitive styles provided more detail explanation compared to FI students. In term of the content, square is defined as: (1) a quadrilateral with equal length sides and equal right angles or (2) a rhombus which has right angles, or (3) a rectangle which every adjacent sides are equal [20]. All of the participants formulated the similar definition of square as definition (1) by considering the equal sides and equal length, but not mentioning the quadrilateral. However, when they were asked to draw, they correctly draw a square as a quadrilateral with equal length and all right angles. The incomplete written or oral definition also found previously in the study of Utami [21]. The study revealed that the common error in communication is happened due to incomplete explanation of certain concept.

After understanding the problem, the students work to solve it step by step until they come to the solution. The final result of them were generally correct, except one minor calculation of WFD which leads her to incorrect answer. She realized her mistake during interview and she was able to fix it and get the right one. From that, it can be seen that the students performed well in solving the problem.

Many factors influenced the process of problem solving, e.g. the mathematics basic knowledge, the use of formulas/models/representations, and the use of mathematical language/notation from the beginning until a conclusion can be drawn. In this case, the students' fluency in working with the problem is understandable as they basically have a good mathematical basic skill. They have no difficulties in basic operation applied in real

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numbers. Despite of making errors in several parts if they did it the calculation hurriedly, they knew the procedures of counting and calculating.

In term of the use of formulas/models/representations, the students were able to apply the formula of the area of the square as the multiplication of its two sides (written as $s \times s$) and the area of the rectangle as the multiplication of its length and width ($p \times l$). They can properly write and apply the formula. However, when they were asked how can the formula of the area of square can be determined by $s \times s$ and rectangle by $p \times l$, they cannot give any explanation, besides that it was given by the teacher. They also stated that they are remembering the formula since their elementary school time, especially in fourth grade. Here, our study found that the students were not understood the formula they have been memorized. This is contrary with the study of Novitasari which stated the students are allowed to memorize if they understood it [22].

After calculated the area of the square and the rectangle, the students started to encounter the original problem. They connect and compare the information given in the text and picture. The following explanation summarized how the students construct the mathematical model based on the information in the problem.

a. The FI students (male and female) saw the picture as two combination shapes, hence it can be separated into two parts again to see its mathematical model. To finish the problem, these two objects can be recombined.
b. The FD students (male and female) saw the picture as one whole, even though in her heads the separation of object into two parts were also happened. In the end, she constructed only one mathematical model.

Based on the students' model construction it can be observed that FI students tend to be more details in writing the process of the problem solving. This is in line with the previous study that found how FI students tend to be more precise in thinking and explaining [10]. In the gender point of view, the distinction cannot be distinguished as the result focus on the impact of cognitive style.

In term of mathematical language, all of them using their notation that influenced by their learning experiences. All of them were come from different elementary school. They also assign in different class during their participation on this study, but they were taught by the same mathematics teacher. The following summary explained how the students employed mathematical language during the problem solving.

a. The female student with FI cognitive style was using some symbols to explain the solution of the given problem. She used pictures, alphabets and their combination.
b. The male student with FI cognitive style was using less symbols to explain his process in solving the problem. He used alphabets and Roman numerals, but not the combination of it to create new symbol and new definition.
c. The female student with FD cognitive style was using some symbols to explain the solution of the given problem. She employed alphabets, Roman numerals, pictures and their combination.
d. The male student with FD cognitive style merely used symbol with single alphabet.

The students were using different symbols, nonetheless they unaware to introduce the meaning of the symbols in the work sheet. Furthermore, according to the construction of symbols, it can be seen that female students were more productive than the male students who employed fewer symbols. Also, the FI students were slightly more productive compared to FD in using symbols.

From those, it can be concluded that the students' abilities in using mathematical languages and symbols affected more by gender differences instead of the cognitive styles. Besides looking at written solution of the students, in the end of the test the

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students were also asked to explain their answer orally during the interview. The results of every subject can be summarized as follows.

a. The female student with FI cognitive style was able to communicate her idea completely in oral explanation, but incomplete in written. She also wrote a lot of symbols, combine it to define a new meaning, but still inconsistent. In oral explanation, she is fluently talking, supported by a clear voice and proper intonation. The overall process was complete but inaccurate due to incorrect information.
b. The male student with FI cognitive style was able to solve the problem, but the oral communication was not fluent. Some parts were mispronounced. His voice was low and there were gaps between explanation. However, he provided explanation from the beginning to the process and even the looking back step.
c. The female student with FD cognitive style was able to solve the problem, focus on the numbers instead of the whole problem. In oral explanation, her voice was low but she talked fluently. She was able to explain her ideas from beginning until checking process in the end.
d. The male student with FD cognitive style was able to solve the overall problem, but hesitate in oral explanation. He used clear voice with gap in between. He started his explanation from how he understood the problem and how he worked and check the result.

According the information above, it can be seen that the female students provide better oral explanation compared to the male students. However, we cannot clearly draw the differences among the cognitive styles since the female in FI was more fluent than female in FD; but male in FD do better compared to male in FI. It is very likely that females' fluency supported by their creativity and critical thinking as study showed girls are more creative [23] and more critical [24]. Those findings explained why females have better foundation to develop better communication skill.

In general, there are some remarkable notes related to students' mathematical communication ability found in junior high school level. First, the students encountered difficulties in describing geometry pictures both orally and verbally. Second, they also tend to use symbols meaninglessly, no further information related to the symbol. It leads to the inconsistent used of symbols in the process of problem solving. Last, the students' oral explanation of steps in solving the problem were incomplete.

The findings of the study may be used to support the improvement of learning activities in the classroom. One recommendation is to bridge the students' communication skill and to minimize the aforementioned obstacles by using the multi-representation of mathematical objects. The previous studies found that intertwinement between mathematical representations enable students to grasp with the general idea of the concepts and communicate it verbally and orally [23] & [24].

4. Conclusion

The results of the study provide a description of students' mathematical communication skills in problem solving for every subject which represents different cognitive styles and gender differences. From the analysis it was found that many differences occurred on the communication aspects based on the differences in cognitive styles and gender. In general, it can be seen that female students more fluent in explain their work orally and also skillful in the use of symbols compared to the male students. However, the comparison in term of cognitive styles still hard to draw based on the findings of the study.

Overall, this study had limitation in describing the background of the gender aspect of the participants. Here, the social and cultural influences were not thoroughly examined before the test. Therefore, for the researchers who interest to continue the topic of gender

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differences and its impact to the communication, especially in mathematics, may consider the roles of social and cultural background as those aspects play important role in defining gender characters. Besides that, the mathematical content to explore in further studies may take different topic, i.e. social arithmetic. It will be challenging to take topic with various communication tools, e.g. oral, verbal and visual that can be presented through text, story pictures, animation, video, etc., in the classroom. For instance, the setting of market where buyer and seller meet and doing transaction.

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