Gender differences in algebraic thinking ability to solve mathematics problems

W Kusumaningsih1,2*, Darhim1, T Herman1 and Turmudi1
1Departemen Pendidikan Matematika, Universitas Pendidikan Indonesia, Bandung, Indonesia
2Pendidikan Matematika, Universitas PGRI Semarang, Semarang, Indonesia

*Corresponding author’s email: widya.kusuma81.wk@gmail.com

Abstract. This study aimed to conduct a gender study on students' algebraic thinking ability in solving a mathematics problem, polyhedron concept, for grade VIII. This research used a qualitative method. The data was collected using: test and interview methods. The subjects in this study were eight male and female students with different level of abilities. It was found that the algebraic thinking skills of male students reached high group of five categories. They were superior in terms of reasoning and quick understanding in solving problems. Algebraic thinking ability of high-achieving group of female students also met five categories of algebraic thinking indicators. They were more diligent, tenacious and thorough in solving problems. Algebraic thinking ability of male students in medium category only satisfied three categories of algebraic thinking indicators. They were sufficient in terms of reasoning and understanding in solving problems. Algebraic thinking ability group of female students in medium group also satisfied three categories of algebraic thinking indicators. They were fairly diligent, tenacious and meticulous on working on the problems.

1. Introduction
Algebraic thinking can be interpreted as an approach to quantitative situations that emphasize the aspect of general relations using tools that are not necessarily symbols, but can be used as cognitive tools to introduce and retain more traditional school algebra discourse [1]. Some experts define algebraic thinking, one of which is Ameron, defining that, “algebraic thinking is mental process like reasoning with unknown, generalizing, and formalizing relation between magnitude and developing the concept “variable”. It can be interpreted that algebraic thinking is a mental process with something unknown, generalize, and make the relationship formula between the scale and build the concept of variables [2]. It is important for teachers to know students' algebraic thinking skills, especially higher secondary students in solving a mathematical problem. Teachers need to understand how students think and reason algebraically. This is important, as teachers’ consideration when giving materials such as linear programs, equations and inequalities, exponentials and logarithms, etc. where the ability to use algebraic forms and algebraic solutions is necessary. This is in accordance with the opinions of Kamol and Har that, in order to develop student learning in mathematics, it is important to understand the development of students' thinking and reasoning [3].

According to Ntsohi, algebraic thinking is the use of mathematical symbols and tools to analyze conditions differently by representing information mathematically in terms of words, diagrams, tables,
graphs and equations and use mathematical findings such as unknown value settlement, test the proof and look for the relationship of a function [4].

Substantiate the algebraic thinking, Kriegler indicates that there are two components in algebraic thinking, that is the development of mathematical thinking tools and the study of the basic ideas of algebra. The mathematical thinking tool consists of three categories, tools for problem-solving skills, representational skills, and quantitative reasoning abilities. While the basic idea of algebra in question is algebra as a form of arithmetic generalization, algebra as the language of mathematics, and algebra as a tool for the function and modeling mathematics [5].

Algebra is needed in times of school. However, in adult life algebra is also important to be in need during times of work even during life, human needs algebra. In the Piaget thinking stage, students at the age of 7 - 15 years are at the formal operational stage. At this stage, people have started to think about the experience beyond concrete experience, and think in a more abstract, idealistic, and logical. Concrete operational thinkers need to see concrete elements A, B, and C to draw the logical conclusion that if A = B and B = C, then A = C. By contrast, formal operational thinker can solve this problem even if this problem is only presented verbally [6].

Problems are something that is not separated from human life. Because the problem is a gap between hope and reality. People often expect, but the reality is not in line with expectations. From a problem, humans are not only burdened, but problems means of finding new knowledge. According to Gagne, if a student is faced with a problem, then in the end they not only solve the problem, but also learn something new [7]. Problem solving becomes a key process in learning, especially in science and math. So that problem solving becomes one of the abilities taught in a learning. Dale and Wilson also said problem solving has special importance in the study of mathematics. By looking at the importance of problem solving, this is the underlying reason why problem solving becomes central to mathematics learning. Problem solving is the invention of a suitable way to achieve a goal [8,9].

As Dale said students' mathematical abilities are 3: high, medium, and low. Students with high math skills in solving algebra problems meet three indicators: the unstructural level, the multistructural level, and to relational level. Students with math ability are fulfilling two indicators, they are unstructural level and multistructural level [8]. While low mathematics students only meet one indicator that is unistructural level. Based on the description, so the author only take the subject of research on students who are high-ability and moderate, because high-ability students and are able to analyze information that is clear from the problem, able to calculate, and able to replace variables appropriately.

Student's thinking ability is also influenced by some things that are not less important, such as gender factor. Gender differences between males and females occur through a very long process, such as through the process of socialization, religious teachings and state policy, so that differences are perceived and understood as the nature of men and women. As Santrock said that gender more specifically refers to the characteristics of men and women [10]. Meanwhile, Eckert said "gender is not something we are born with, and not so we have, but something we do". Eckert added "gender is something we perform". Based on these definitions, it can be concluded that the concept of gender is a character of men and women formed by society both culturally and socially [11]. Differences in the ability of males and females bring about the attention of educational researchers and become an interesting variable in the study. The purpose of this research is to study the algebra thinking abilities of male and female students of high and medium group on the polyhedron subject matter.

2. Methods
This research is a descriptive qualitative research used to find the meaning or essence behind the symptoms that happened in research subject. This means that this research aims to reveal students' algebraic thinking skills during the teaching and learning process, especially on the subject matter of polyhedron.

The researcher took the sample based on the daily test result of the polyhedron in grade VIII students, then the researcher with the help of the mathematics teacher of the class selected eight
students which were grouped into four groups, two male students with high score, two female students with high score, two male students with moderate score, and two female students with moderate score. Data collection techniques in this study include written tests, interviews, and data triangulation techniques.

3. Result and Discussion

Results and discussion of students' algebraic thinking skills in solving mathematical problems using the five components of algebraic thinking by Kriegler are: 1) Algebra as a language of mathematics, indicators: Students are able to explain the meaning and function of variables, students are able to use variables to show information that is known or unknown, students are able to explain the meaning of the result of problem solving, students are able to do algebraic manipulation on an algebraic equation, students are able to determine the value of the variable being asked; 2) representational ability, indicators: students are able to represent the information relation of the question, students are able to create various forms of representation from question, student can explain information obtained from representation made; 3) problem solving ability, indicators: student is able to identify known and questioned element, student can choose problem solving strategy, student can solve problem using strategy chosen, the student can checks the accuracy of his chosen strategy and checks the correctness of the problem solving, students can explain other approaches / solutions to open problems; 4) quantitative reasoning skills, indicators: students are able to answer the problem correctly with the right reasons, students are able to use the operations of the algebra, students can use inductive or deductive reasoning in the problem; 5) and algebra as a tool for mathematical functions and modeling, indicators: students are able to use patterns / rules in the form of words / equations, students are able to represent mathematical ideas on each question using equations, inequality, tables, graphs, or words appropriately and consistently. In this study five questions of algebraic thinking ability are interrelated. The rubric of assessment of each algebraic thinking ability component is tabulated in Table 1.

| Rubric of assessment of each algebraic thinking ability component |
|---------------------------------------------------------------|
| Students' ability | Algebraic thinking ability level of each component | Category |
|                  | High | Medium | low       |           |
| High             | 5    | 0      | -         | Good      |
|                  | 4    | 1      | -         | Good      |
|                  | 3    | 2      | -         | Good      |
| Medium           | 2    | 3      | -         | Middle    |
|                  | 1    | 4      | -         | Middle    |
|                  | 0    | 5      | -         | Middle    |

The male students subject with high-ability (SL1) meets all the indicators of algebraic usage as a mathematical language, which is capable of using and explaining the intent of symbols to indicate known information, capable of algebraic manipulation and capable of determining the value of a variable even though it is wrong in understanding the problem. Subject SL1 is able to create modelling. The SL1 subject meets an indicator performing a symbolic representation by creating an equation. In addition, from the results of the written test and the SL1 subject interview in solving the problem number 4, it appears that the SL1 subject uses mathematical findings and meets all the problem solving indicators. The problem solving indicator is capable of answering known and questionable elements and checking the chosen problem solving strategy.

The female students subject with high-ability (SP4) meets all the indicators of algebraic usage as a mathematical language that is capable of using and explaining symbolic meaning to show known information, capable of performing algebraic manipulations and being able to determine the value of
variables. Thus, the subject of SP4 can be said to be in a good category on the use of symbols, although it is still wrong in understanding the question. The SP4 subject correctly makes the modeling of the information made, although there is a slight misunderstanding made by SP4 subject. Then the SP4 subject meets the indicator capable of performing a symbolic representation that is able to create an equation. In addition, from the results of the SP4 subject’s written test and interviews in solving the question number 4, it appears that the SP4 subject uses mathematical findings and meets all the problem solving indicators. The problem solving indicator is answering the exact known and asked element, checking the selected problem solving strategy and yet the SP4 subject does not check the correctness of the problem solving. Then, the indicator of quantitative reasoning ability that is met by SP4 subject based on the above data exposure is that SP4 subject using deductive reasoning, and capable of performing algebraic operations. From the above analysis data on SL4 and SP4 subjects it is found that high-ability male students have better mathematical abilities than high-ability female students. This is consistent with Krutetski’s statement explaining that men have better mathematical and mechanical abilities than women, this difference is not real at the primary school level but becomes more apparent at a higher level [12].

The male students with medium-ability (SL6) meets in part the the indicators of algebraic usage as a mathematical language, which is capable of using and explaining the intent of symbols to indicate known information, capable of algebraic manipulation and capable of determining the value of a variable even though it is wrong in understanding the problem. Subject SL6 is able to create modelling. The SL6 subject meets an indicator performing a symbolic representation by creating an equation. In addition, from the results of written tests and subject interviews SL6 in solving the problem number 4, has not seen that the subject of SL6 using mathematical findings. The SL6 subject problem-solving indicator is not yet able to answer the known elements correctly.

The female students subject with medium-ability (SP5) meets in part the indicators of algebraic usage as a mathematical language that is capable enough of using and explaining symbolic meaning to show known information, capable enough of performing algebraic manipulations and being able to determine the value of variables. Thus, the subject of SP5 can be said to be in a medium category on the use of symbols, although it is still wrong in understanding the question. The SP5 subject correctly makes the modelling of the information made, although there is a slight misunderstanding made by SP5 subject. Then the SP5 subject meets the indicator capable enough of performing a symbolic representation that is able to create an equation. The SP5 subject makes the modelling and equation of the information made less precise, then the SP5 subject meets the indicator is quite capable of performing symbolic representation. From the results of the written tests and interviews SP5 subject in solving the problem number 4, it appears that the subject of SP5 is not so clear in solving the problem. From the analytical data on the subject of SL6 and SP5, it can be seen that male students with moderate abilities also have better math skills than female students with medium abilities. From the above analysis data on SL6 and SP5 subjects it is found that medium-ability male students have better mathematical abilities than medium-ability female students.

Gender differences affect students’ algebraic thinking skills, when observers observe factors of thoroughness, female students tend to be more rigorous, marked when working on the question of female students often checking back what is written and asking a lot when not adequately understanding the questions given, men tend to be more indifferent, directly do what they receive, and do not check back answers that have been written. Then male students are superior in reasoning compared to female students, female students are superior in accuracy, for example accuracy in choosing problem-solving strategies on the number 4 is trap, because in the matter already known one of the variables. Male students in learning styles are easier to capture, than female students, but female students are more active in learning, so that sometimes female students are superior to male students.

4. Conclusion
It can be concluded that the algebraic thinking skills of male students reach high group met five categories which were superior in terms of reasoning and quick understanding in solving problems.
The algebraic thinking ability of female students of high-achieving group met five categories of algebraic thinking indicators. They were also found to be more diligent, tenacious and through in solving problems. The algebraic thinking ability of medium category male students only satisfied three categories of algebraic thinking indicators. They were sufficient in terms of reason and understanding in solving problems. The algebraic thinking ability of medium female students satisfied three categories of algebraic thinking indicators. They were fairly diligent, tenacious and meticulous on working on the problems.

5. References
[1] Kieran C 2004 Algebraic Thinking in the Early Grades: What Is It? The Mathematics Educator 8 1 139-151
[2] Ameron and Van B A 2002 Reinvention of Early Algebra (Utrecht: Freudenthal Instituut)
[3] Kamol, Natcha and Har Y B 2002 Upper Primary School Student Algebraic Thinking (Chiang Mai University)
[4] Ntsohi M M 2013 Investigating Teaching And learning of Grade 9 Algebra Through Excel Spreadsheet : A Mixed-Methods Case Study For Leshoto (Stellenbosch University)
[5] Kriegler and Shelley 2002 “Just What is Algebraic Thinking?” , Algebraic Concepts in the Middle School A Special Edition of Mathematics Teaching in the Middle School
[6] NCTM 2000 Principles and Standards for School Mathematics (USA: NCTM)
[7] Gagne R M 1984 Conditions of Learning (Jakarta: Depdikbud Dirjen Pendidikan Tinggi)
[8] Dale H and Schunk 2011 Learning Theory: Educational Perspective (Yogyakarta: Pustaka Pelajar)
[9] Wilson 2012 Human Resource Management (Erlangga, Jakarta)
[10] Santrock 2011 Life-Span Development (Jakarta: Erlangga)
[11] Eckert P and Sally McConnel–Ginet 2003 Language and Gender (UK: Cambridge University Press)
[12] Krutetskii V A 1976 The Psychology of Mathematical Abilities in School Chidren (Chichago: The University of Chicago Press)