Profile of mathematical reasoning ability of female students based on self-efficacy

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Abstract. Reasoning was an important aspect for solving the linear programming problems. Furthermore, the male students performed the spatial ability tests better than the female students. The female students solved the problem by creating a solution plan and looked at the keywords in the problem. This research used qualitative research. The subjects of this research were the of 11th grade of senior high school students taken by using purposive sampling. The techniques of collecting data used in this research were a linear program problem test and self-efficacy questionnaire. The research result revealed that the female students who had high self-efficacy in mathematical reasoning ability explained the use of models, facts, properties, relations to use pattern and relations to analyze the mathematical situation; provided an explanation about the models, the pictures, the facts, the natures, the relationships or the existing patterns; and did mathematical manipulations. In addition, the female students who had medium and low self-efficacy in mathematical reasoning ability were able to draw the analogy, the generalization and could use of pattern and the relation to analyze the mathematical situations and provided an explanation about the models, the pictures, the facts, the natures, the relationships or the existing patterns.

1. Introduction
Mathematics is an excellent tool for improving a person’s intellectual competence in logical reasoning[1]. Reasoning is an important aspect of mathematical ability in learning mathematics because reasoning is needed in solving mathematical questions[2]. Therefore, the students must have a good mathematical reasoning ability in preparing evidence when they have to solve the mathematical problems[3].

Based on the interview with a senior high school math teacher in Sukoharjo, it was found that the students’ reasoning process was not yet developed well. The evidences gained showed that the students had lack of mathematical reasoning. The students learned the basic concepts of numerical operations and solved arithmetic operations in positive integers without having a problem. In fact, they faced difficulties in determining the arithmetic operation results on negative integers and fractions[4].

The previous research found that there were consistent sex differences favoring the male students in mathematical reasoning ability[5]. In accordance with [5], [6], and [7], it showed that the male students performed the spatial ability better than the female students in the test. A study showed that the female students solved the problem by creating a solution plan and looked at the key words in the problems. Meanwhile, the male students solved the problem by making a plan of solutions and paid full attention to the meaning of the sentences[8]. So here, the researchers wanted to investigate the profile of mathematical reasoning ability in the female students.
Another researcher stated that reasoning is an important tool in mathematics and in daily life since many problems in mathematics and in daily life require reasoning to be solved[9]. One of the materials in mathematics related to the real life is linear programming. It is because the process of solving a linear programming problem is a complex process for the students. The complexity of this process causes that every instruction of the word problem solving is needed to make the strategies efficient[10]. In this case, every student must own mathematical reasoning to get an efficient strategy.

In an effort to improve the students’ cognitive and affective outcomes in mathematics and/or in the school learning, the educational psychologists and mathematics educators found that self-efficacy was a variable attracted the educational achievement researcher[11]. This research also demonstrated that the self-efficacy beliefs were different in gender. The relationship between gender and self-efficacy had also been a focus in self-efficacy research. The researcher in that research reported that the high school male students tended to be more confident than the female students in mathematics, science, and technology [12][13].

The study of mathematical reasoning quality plays an important role in influencing the learning environment to improve the students’ mathematical reasoning abilities. This research analyzed more deeply about the profile of the students’ mathematical reasoning ability of the female students based on self-efficacy.

2. Research Methods

The design of this research was a qualitative descriptive approach. The qualitative and descriptive research methods have become the common procedures in conducting the research in many disciplines, including education [14]. The goal of this research was to observe naturally the students’ mathematical reasoning based on self-efficacy. The research was conducted in the second grade class of a senior high school in Sukoharjo in the academic year of 2018/2019. The research sample was set on 10 second grade female students. The research began with the provision of self-efficacy questionnaire.

The sampling was done by dividing the 10 female students into three categories which were high self-efficacy, medium self-efficacy, and low self-efficacy. The data were obtained by interviews and test methods. The interview method was used to know the students’ difficulties in understanding the process of reasoning. Meanwhile, the tests were used to measure the students’ mathematical reasoning ability in linear program word problem. So, the mathematical reasoning tests consisted of a linear program problem and were outlined in the mathematical reasoning indicators. A description of the mathematical reasoning indicators used in this research is shown in Table 1.

Table 1. Description of indicators.

| No | The Mathematical Reasoning Indicators | The Sub Indicators |
|----|--------------------------------------|-------------------|
| 1  | Drawing analogy and generalization [15][16][17] | (1) Stating what is known in the problem completely |
|    |                                                      | (2) Showing the variables related to the linear inequalities problems |
|    |                                                      | (3) Capable to express the problem into mathematical models well |
| 2  | Explaining the use of models, facts, properties, and relations [15][17] | (1) Capable to form the mathematical model of the problems properly |
|    | Using pattern and relation to analyze the mathematical situations to provide an explanation of the models, the pictures, the facts, the natures, the relationships or the existing patterns [17] | (2) Capable to substitute the values into the mathematical model of the problem properly |
| 3  |                                                      | (1) Sketching the set areas solution graph of the two inequalities linear variables |
| 4  | Doing mathematical manipulations [16] | (1) Calculating the operations in algebra form well and properly |
|    |                                                      | (2) The steps of completion by using the elimination, substitution, or graphic method are done correctly |
|    |                                                      | (3) Finding the values of variables properly |
| 5  | Making conclusions [15][17] | (1) Writing down the problem solutions by using daily word well |

The triangulation was used to make sure the validity of the data. The validation process of the data validity was done by comparing the information between the test result data and the interview
data. The stages of data analysis in this research are: (1) giving questionnaire about self-efficacy to the students; (2) categorizing the students into three categories of self-efficacy which are high self-efficacy, medium self-efficacy, and low self-efficacy; (3) giving mathematical reasoning tests to the students; (4) analyzing the test results; (5) conducting the interviews to the students as the research subjects; and (6) analyzing the interview results.

3. Results and Discussion
The research subjects were taken by using purposive sampling. The purposive sampling is a nonrandom technique that does not need underlying theories or a set number of participants so the researcher decides what are needed to be known and sets out to find people who can and are willing to provide the information by virtue of the knowledge or the experience [18].

Previously, the students were categorized into three categories which were the students with high self-efficacy, the students with medium self-efficacy, and the students with low self-efficacy. In each category, one student was taken so the total subjects for the data collection in this research were 3 students. The students were selected based on the consideration of their mathematics teacher.

3.1. Results
The students' answers were corrected and grouped into five indicators of mathematical reasoning. Furthermore, the summary of the sub-indicators of the mathematical reasoning result outlined in Table 1 done by the students could be seen in the Table 2 and the mathematical reasoning ability performed by each subject would be discussed further.

| No | Indicators                                                                 | The Number from Subindicators | Mastered by SH | Mastered by SM | Mastered by SL |
|----|---------------------------------------------------------------------------|-------------------------------|----------------|----------------|----------------|
| 1  | Drawing the analogy and the generalization [14,15,16]                      | 2,3                          | 1,2,3          | 1,2,3          |
| 2  | Explaining the use of models, facts, properties, and relations [14,16]    | 2                             | -              | -              |
| 3  | Using pattern and relation to analyze mathematical situation to provide an explanation of the models, the pictures, the facts, the natures, the relationships or the existing patterns [16] | 1                             | 1              | 1              |
| 4  | Doing mathematical manipulations [15]                                     | 1,2,3                        | -              | -              |
| 5  | Making conclusions [14,16]                                                | -                            | -              | -              |

From the Table 2, it could be concluded that the female student with high self-efficacy satisfied the indicators of the mathematical reasoning tentatively. A female student with high self-efficacy could fulfill 7 sub-indicators from 10 mathematical reasoning ability sub-indicators.

3.1.1. Student with high self-efficacy. The student who was taken from the high self-efficacy category students as the subject was SH. On the linear programming problem given as a test to measure the students' reasoning abilities in daily life word problems, she could draw the analogy and the generalization. However, she did not carry out the sub-indicators outlined in Table 1. She could not state what was known in the problem completely. It can be seen in Figure 1 that she directly composed the mathematical model without writing down the information known from the question completely.
In the mathematical reasoning ability for the indicator of explaining the use of models, facts, properties, and relations, SH did not fulfill all of the sub-indicators on the Table 1. She was capable to substitute the values into the mathematical model from the problem properly but the structures of the mathematical model were less detailed and the information from the test problem given was not written completely as shown in Figure 2. So, it could be concluded that the students with high self-efficacy were excellent to represent problems into the mathematical models by using the appropriate symbols and tools as showed in the figures below[19].

According to Figure 3, SH could sketch the set areas solution graph of the two inequalities linear variables properly.
substitution, or the graphic method correctly, and find the values of the variables properly. Nevertheless, she could not write down the problem solutions by using daily word well.

From the description explained, the mathematical reasoning ability mastered by the female student with high self-efficacy in solving the linear programming problems of the linear program material was doing the mathematical manipulation.

3.1.2. Student with medium self-efficacy. The student who was taken from the medium self-efficacy category students as the subject was SM. On the linear programming problem given as a test in daily life word problems, she could draw the analogy and the generalization. She carried out the sub-indicators outlined in the Table 1 properly. It can be seen from the interview result conducted by the researcher along with her.

Q : What was the purpose of the problem given?
SM : It asked to make the mathematical models, look for the extreme points, and the maximum profits.
Q : What was your first step?
SM : Wrote down whatever information known.
Q : What was known?
SM : The purchase price of the shirts and the trousers, the selling price, the fund, and the maximum store load of the clothes.
Q : What was your next step?
SM : Assumed the number of the shirt as $x$ and the number of trousers as $y$ Miss, and then formed the tables. From the tables, I can form a mathematical model.

The result showed that SM directly composed a mathematical model completely. So, she could state what was known in the problem completely, show variables related to the linear inequalities problems, and express the problems into the mathematical model well.

She could not explain the use of models, facts, properties, and relations because she did not carry out the sub-indicators from the indicator of explaining the use of models, facts, properties, and relations which was outlined in Table 1. From the interview conducted by the researcher, she was able to express the problem into the mathematical model well but she could not form the mathematical models of the problems properly. It can be seen in Figure 4.

![Figure 4. Result of mathematics form by SM](image)

SM could sketch the set areas solution graph of the two inequalities linear variables properly. She was not able to do the mathematical manipulation. It was because she could not calculate the operations in algebra form well and properly. It can be seen in Figure 4 that she could not simplify the equations.

She did not write down the solution steps completely. Moreover, she could not show the best solution for solving the linear programming problems and could not write down the problem solutions by using daily word well.

From the description explained, it can be concluded that the mathematical reasoning ability mastered by the female student with medium self-efficacy in solving linear programming problems of the linear program material was drawing the analogy and the generalization.
3.1.3. **Student with low self-efficacy.** The student who was taken from the low self-efficacy category students as the subject was SL. On the linear programming problem given as a test as daily life word problems, she could draw the analogy and the generalization. She also carried out the sub-indicators outlined in Table 1 properly. It can be seen from the interview between the researcher along with her.

Q : What was the purpose of the problem given?
SM : It asked to search mathematical models, looking for the extreme points, and the maximum profits.
Q : What was your first step?
SM : Wrote what was known and what was asked firstly then continued the writing from the point made it inequal.
Q : What was known?
SM : The price of the shirts and the trousers, the selling price, the fund, and the maximum store load of the clothes.
Q : What was your next step?
SM : Assumed the number of the shirt as $x$ and the number of the trousers as $y$ Miss, and then I formed it into a mathematical model.

From the interview, SL directly composed a mathematical model properly. So, she could state what was known in the problem completely, show the variables related to the linear inequalities problems, and express the problems into the mathematical model well.

She could not explain the use of models, facts, properties, and relations because she did not carry out the sub-indicators from the indicator of explaining the use of models, facts, properties, and relations which was outlined in Table 1. In Figure 5, she could not form the mathematical models of the problems properly because she made mistakes in the reading error category. Below are the linear programming word problems given to her.

A patient should drink at least 50 units of vitamin A and 32 units of vitamin B from two types of tablets every day. Tablet Y contains 10 units of vitamin A and 4 units of vitamin B. The price of the tablet X is IDR 3000/pcs and the tablet Y is IDR 5000/pcs.

a. Make a mathematical model of the problem!
b. Make a graph of the function and determine the extreme points!
c. Calculate each number of tablets X and Y that must be purchased so the costs incurred are minimum!

Allegedly she was rushing in reading the question or did not pay attention to the word "at least" so she created a wrong mathematical model and could not form the mathematical models of the problems perfectly.

![Figure 5. The Mathematic Form Result by SL](image)

According to the Figure 5, SL could not sketch the set areas solution graph of the two inequalities linear variables properly because she made an error in creating the mathematical model.

SL was as same as SM because they had the same mathematical ability in doing mathematical manipulation. SL could not calculate the operations in algebra form properly. She also did not write down the solution steps completely. Furthermore, she could not show the best solution for solving the linear programming problems and could not write down the problem solutions by using daily word properly.
Another research showed that the low self-efficacy student only used reflective thinking steps at one problem solving stage. In other words, the students with low self-efficacy have the weakest reflective thinking abilities among high and medium self-efficacy students [20]. But in this research, the students with medium and low self-efficacy had the same reasoning abilities in solving the linear program problems.

From the description explained, the mathematical reasoning ability dominated by the female student with low self efficacy in solving the linear programming problems of the linear program material is same with SM which is drawing the analogy and the generalization and draw the analogy, the generalization and could use of pattern and the relation to analyze the mathematical situations and provided an explanation about the models, the pictures, the facts, the natures, the relationships or the existing patterns.

3.2. Discussion
The results showed that the students still experienced the difficulties in mathematical reasoning. Almost every student could not face mathematical reasoning properly.

The female student with high self-efficacy could draw the analogy and the generalization. However, she did not carry out the sub-indicators and could not state what was known in the problem completely. Moreover, she directly composed the mathematical model without writing down the information known from the question completely. In the indicator of explaining the use of models, facts, properties, and relations, she also did not fulfill all of the sub-indicators in it. She was able to substitute the values into the mathematical model of the problem properly but the structure of the mathematical model made was less detailed and the information from the problem given was not written completely. In addition, she could sketch the set areas solution graph of the two inequalities linear variables properly then she could do the mathematical manipulation. It was because she could calculate the operations in algebra form properly, complete the solution steps by using the elimination, the substitution, or the graphic method correctly, and find the values of the variables properly. Nevertheless, she could not write down the problem solutions by using daily word well. Based on the result, it could be concluded that the mathematical reasoning ability mastered by the female student with high self-efficacy in solving the linear programming problems of the linear program material was doing the mathematical manipulation.

On the linear programming problem test using the word problems related to the real life, the female student with medium self-efficacy could draw the analogy and the generalization, carried out the sub-indicators outlined in Table 1 properly, and composed the mathematical model completely. So, she could state what was known in the problem completely, showed the variables related to linear inequalities problems, and expressed the problems into the mathematical model well. She could not explain the use of models, facts, properties, and relations because she did not carry out the sub-indicators from the indicator of explaining the use of models, facts, properties, and relations. The female student with medium self-efficacy expressed the problems into the mathematical model well but she could not form the mathematical models of the problems properly. She could sketch the the set areas solution graph of the two inequalities linear variables properly. Unfortunately, she could not do the mathematical manipulation because she could not calculate the operations in algebra form properly. Moreover, she did not write down the solution steps completely, could not show the best solution for solving the linear programming problems and could not write down the problem solutions by using daily word well. From the description explained, it could be concluded that the mathematical reasoning ability mastered by the female student with medium self-efficacy were able to draw the analogy, the generalization and the use of pattern and the relation to analyze the mathematical situations and provided an explanation about the models, the pictures, the facts, the natures, the relationships or the existing patterns.

The same results with a female student from medium self-efficacy category, on the problem of linear programming that was given as a test as word problems in daily life, a female student with low self-efficacy could draw analogy and generalization because a student carried out the subindicators
properly. A student composed a mathematical model properly. So, low self-efficacy student could state what is known in the problem completely, showed variables related to linear inequalities of problems, and was able to express the problem into mathematical model well. This student could not explain the use of model, facts, properties, and relation because the student did not carry out the subindicators of indicator explain the use of model, facts, properties, and relation. In addition, student could not form mathematical models of problems properly because student made mistakes in the reading error category. As a results, the student could not form mathematical models of problems perfectly. Moreover, a female student from low self-efficacy category could not sketch graph of solution set areas of two variabels linear inequalities properly because error in the mathematical model created by herself.

The female student from low self-efficacy category as same as from medium self-efficacy category because of their mathematical ability in doing mathematical manipulation. A student with low self-efficacy could not calculate the operations in algebra form properly, did not write down the step solution completely, and could not show the best solution for solving the linear programming problem and could not write down solution problem with daily use word properly.

From the description, it can be concluded that mathematical reasoning ability dominated by female student with low self-efficacy in solving linear programming problems in the linear program material was same with student from medium self-efficacy category. She was able to draw the analogy, the generalization and the use of pattern and the relation to analyze the mathematical situations and provided an explanation about the models, the pictures, the facts, the natures, the relationships or the existing patterns.

4. Conclusions
According to the results, the different abilities are found in the mathematical reasoning doing by high self-efficacy, medium self-efficacy, and low self-efficacy female students.

First, the female student with high self-efficacy category in the mathematical reasoning ability solves the linear programming problems of the linear program material by doing the mathematical manipulation. Second, the female student with medium self-efficacy category in the mathematical reasoning ability solves the linear programming problems of the linear program material by drawing the analogy, the generalization and the use of pattern and the relation to analyze the mathematical situations and provided an explanation about the models, the pictures, the facts, the natures, the relationships or the existing patterns.

The last but not least, the female student with low self-efficacy category in the mathematical reasoning ability solves the linear programming problems of the linear program material as same as the female student with medium self-efficacy category which is by drawing the analogy and the generalization. It can be concluded that the female students with medium self-efficacy category and low self-efficacy category have the same level of mathematical reasoning ability.

Acknowledgments
The author would like to thank the referees for improving the quality of this article and also SMAIT Nur Hidayah Sukoharjo for the opportunity to do research.

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