Students metacognition in solving mathematical problems based on gender differences

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Abstract. Metacognition has an important role in solving mathematical problems. Metacognition in this study consisted of two components, namely metacognitive knowledge (declarative knowledge, procedural knowledge, conditional knowledge) and metacognitive regulation (planning, monitoring, and evaluation). Through the use of metacognition, students can find out what strategies are used and the difficulties that occur when learning and solving mathematical problems. The purpose of this study was to understand whether or not there were differences in metacognition of male and female students in solving mathematical problems. This study was quantitative research. The study was conducted in 87 students consisting of 55 male students and 32 female students from three junior high schools in Surakarta. The instruments used in this study were questionnaires and essay test. The data analysis technique used is the multivariate F-test. The result of this study is that there are differences in metacognition of male and female students in solving mathematical problems. The difference lies in the components of the metacognitive regulation, namely planning, monitoring, and evaluation.

1. Introduction
Mathematics is one of the science that has an important role in the education field [1]. It is because mathematics helps the development of other sciences. Through the application of mathematics, a person can solve the problem easier, more effective, and more efficient [2]. The problems in mathematics are the problems which contain mathematical concepts and are presented in the form of both non-routine questions and word questions [3]. Students consider a question as a problem if students find difficulties in solving the problem by the knowledge they have.

Problem solving has been considered as an important and inseparable aspect from the mathematics learning process [4]. Lester in Anggo and Sahidin stated that the main objective of problem solving in mathematics learning is not only to equip the students with certain skills or abilities, but rather to enable students to think about what they think [5]. Problem solving activity not only involves cognition but also requires the thinking awareness of students to control and to regulate their thinking processes or commonly called as metacognition [6, 7].

Metacognition is the awareness and the ability of a person to control his thinking process [8]. The objective of metacognition is to control all strategies during problem solving and to optimize the cognitive process of students in achieving learning goals [9, 10]. The involvement of metacognition provides a great benefit for subjects which is inseparable with the problems, such as mathematics [8]. Davidson, Stendberg, and Hedlund in Aljabeli stated that metacognition helps students to define the
problem, to choose an effective strategy, to observe the work of a strategy, and to regulate the thinking process of students [7]. The advantage of involving the metacognition process in solving problems is to be able to build a strong, thorough, and deep understanding of mathematical problems [11].

Metacognition has two components, namely metacognitive knowledge and metacognitive regulation [12,13,14]. Metacognitive knowledge refers to the knowledge and the awareness of students about their tasks and their learning strategies [13]. The metacognitive regulation is the action taken by students to control their thinking when they solve the problems [13]. Metacognitive knowledge consists of declarative knowledge, procedural knowledge, and conditional knowledge [12,15]. Meanwhile, the metacognitive regulation consists of planning, monitoring, and evaluation [13,16].

Based on the results of research conducted by Mulyono, the difficulties faced by students when working on problem solving are difficulties in understanding problems, writing known variables, converting variables into mathematical languages, and applying the formulas used [17]. Stacey states that the ability of Indonesian students is still lacking if given problems that require the ability to examine, reason, communicate effectively, resolve and interpret problems in various situations. This is related to the metacognition students have, namely control of their own learning [17]. Many studies have investigated metacognition between female students and male students, but the results are not the same [18]. Some studies show that there were significant differences in metacognition between female students and male students. However, several other studies show that there was no significant difference in metacognition between female students and male students. In addition, such research has never been conducted in Indonesia, especially in Surakarta.

Based on the research, researchers were interested in conducting research on student metacognition. Given the importance of student metacognition in mathematics learning, this study was conducted to determine whether there were differences in metacognition between female students and male students in Surakarta. This type of research has been conducted by Ciascai et al. and Misu et al. but there are differences with the research that the authors did [18,19]. The difference is in the research conducted by Misu et al. comparing the metacognition of female teachers and male teachers, while this study focuses on student metacognition [19]. In addition, the research conducted Ciascai et al. was carried out in Romania, while this research was conducted in Surakarta, Indonesia [18].

2. Method
This research was quantitative research. The population of this study was the 8th grade of junior high school in Surakarta, Indonesia. The sampling technique used stratified cluster random sampling. The study sample was 87 students consisting of 55 male students and 32 female students.

The instrument being used in this research were a questionnaire and essay test. Questionnaires were used to measure metacognitive knowledge students, while essay tests were used to measure metacognitive regulation students. Questionnaires consisting of 15 statements with Likert scale and essay tests consisting of 3 essay questions. Both instruments have been tested for validity and reliability. Validity testing was carried out by experts. The reliability coefficient using Cronbach alpha of the questionnaire was 0.763, while the reliability coefficient using Cronbach alpha of the essay test was 0.701.

The data analysis technique used in this research was the multivariate F-test with a significance level of 0.05. Before the multivariate test was done, the prerequisite test was carried out, namely the normality test and homogeneity test. Data normality test was carried out using the Kolmogorov-Smirnov test and the homogeneity test was carried out by the Box and Levene Test.

3. Results and discussion
3.1. Normality test
The Normality test was used to determine whether the scores of metacognitive knowledge and metacognitive settings of male and female students came from populations that were normally distributed. The result of the normality test was shown in table 1.
Table 1. The results of the normality test.

| Gender  | Variable                  | Kolmogorov Smirnov Statistic | Sig. |
|---------|---------------------------|------------------------------|------|
| Female  | Metacognitive Knowledge   | 0.103                        | 0.200|
|         | Metacognitive Regulation  | 0.123                        | 0.200|
| Male    | Metacognitive Knowledge   | 0.093                        | 0.200|
|         | Metacognitive Regulation  | 0.093                        | 0.200|

Based on table 1 of line 2, it could be observed that the significant p-level of 0.200 was greater than 0.05 (0.200 > 0.05). It means that H₀ was not rejected which indicated that the data of metacognitive knowledge on the sample of female students was taken from the normally distributed population. In Table 1 of line 3 can also be seen that the significant p-level of 0.200 was greater than 0.05 (0.200 > 0.05). It means that H₀ was not rejected which indicated that the data of metacognitive regulation on the sample of female students was taken from the normally distributed population.

Table 1 of line 4 shows that the significant p-level of 0.200 was greater than 0.05 (0.200 > 0.05). It means that H₀ was not rejected which indicated that the data of metacognitive knowledge on the sample of male students was taken from the normally distributed population. In Table 1 of line 5 can also be seen that the significant p-level of 0.200 was greater than 0.05 (0.200 > 0.05). It means that H₀ was not rejected which indicated that the data of metacognitive regulation on the sample of male students was taken from the normally distributed population.

3.2. Homogeneity test

Homogeneity tests were conducted to see whether female students and male students have homogeneous variances. The test result of the variance-covariance matrix homogeneity on metacognition was shown in table 2.

Table 2. The test results of the variance-covariance matrix homogeneity.

| Box’s M | F       | df1 | df2           | Sig.  |
|---------|---------|-----|---------------|-------|
| 1.475   | 0.408   | 3   | 138011,400    | 0.698 |

Based on Table 2 of column 5, it could be seen that the significant p-level of 0.698 was greater than 0.05 (0.698 > 0.05). It means that H₀ was not rejected which indicated that the data on female and male students had the same matrix of variance-covariance on metacognitive knowledge and metacognitive regulation. The test results of the variance homogeneity on metacognitive knowledge and metacognitive regulation were shown in Table 3.

Table 3. The test results of the variance homogeneity.

|        | Statistik | df | df2 | Sig.  |
|--------|-----------|----|-----|-------|
| Knowledge | 0.675     | 1  | 85  | 0.414 |
| Regulation | 0.819    | 1  | 85  | 0.368 |

Table 3 of line 2, it could be viewed that knowledge of metacognitive had significant p-level of 0.414 which was greater than 0.05 (0.414 > 0.05). It meant that H₀ was not rejected which indicated that metacognitive knowledge had the same variance for female and male students. In Table 3 of line 3, it could be observed that metacognitive regulation had significant p-level of 0.368 which was greater than 0.05 (0.368 > 0.05). It meant that H₀ was not rejected which indicated that the data on metacognitive regulation had the same variance for female and male students.
3.3. Multivariate F-test

After the requirements for normality and homogeneity were fulfilled, then a Multivariate F test was carried out. This data analysis technique was used to see whether there were differences in metacognition between female students and male students. The result of the multivariate F-test was shown in Table 4.

| Effect               | F     | Sig. |
|----------------------|-------|------|
| Pillai's Trace       | 6.298 | 0.003|
| Wilks' Lambda       | 6.298 | 0.003|
| Hotelling's Trace   | 6.298 | 0.003|
| Roy's Largest Root   | 6.298 | 0.003|

Based on Table 4 of column 3, it could be observed that the significant p-level of 0.003 which was smaller than 0.05 (0.003 < 0.05). It means that \( H_0 \) was rejected indicating that there were differences in metacognition between female students and male students. The results of this study were in line with the results of the research conducted by Misu et al. [19].

This difference in metacognition was influenced by the factors of motivation and skills in learning mathematics [19]. Female were highly motivated and diligent in learning than male in finishing school assignments [19]. In addition, Iswahyudi in Gista and Yunianta proposed that female students were generally easier to understand the concrete, practical, and emotional things, while male students were easier to comprehend intellectual and abstract matters [20]. This is an agreement with Elliot in Sari et al. conveyed that male student began to be able to demonstrate the results when enrolling secondary school rather than female students, and female students were more accurate and detailed on verbal ability while male students were more critical in various interpretations [21]. The result of the research conducted by Zhu state that female students prefer conventional problem solving using algorithmic strategies while male students use estimation strategies [22]. The strategy shows the metacognitive strategies used when solving problems.

Furthermore, univariate F-tests were conducted to determine whether there are differences in each component (metacognitive knowledge and metacognition arrangements) between female and male students in solving mathematical problems or not. The test result of the univariate F-test was shown in Table 5.

| Variable | F     | Sig. |
|----------|-------|------|
| Knowledge| 2.442 | 0.122|
| Regulation| 8.138 | 0.005|

Based on Table 5 of line 2, it could be seen that the metacognitive knowledge has significant p-level of 0.122 which was larger than 0.05 (0.122 > 0.05). It meant that \( H_0 \) was not rejected which indicated that there was no difference of metacognitive knowledge between female and male students. It can also be interpreted that female and male students have the same awareness of what is known and what is not known about their tasks and learning strategies. Metacognitive knowledge influences the use of strategies so that it is useful for students when students need task completion developed and adapted to their abilities.

Table 5 of the line 3 shows that the metacognitive regulation has significant p-level of 0.005 which was smaller than 0.05 (0.005 < 0.05). It means that \( H_0 \) was rejected which indicated that there was a different metacognitive regulation between female and male students. This research result was parallel with the research conducted by Misu and Masi which explained that every student had different skill in handling a mathematics problem [23]. The metacognitive regulation required the thought about their own thinking process. Students can regulate the process of learning to achieve the goal well and can make own decision independently in the appropriate manner [24].

Alvarez in Oguz and Ataseven
explained that the role of the teachers in the learning process was to help the students in thinking about their learning process whereas the role of the students was responsible toward their learning by thinking, monitoring, and evaluation their learning process [24].

Descriptive statistic of metacognitive regulation between male and female students was shown in table 6.

| Gender | N   | Mean | Std. Deviation | Minimum | Maximum |
|--------|-----|------|----------------|---------|---------|
| Female | 32  | 14.75| 3.992          | 7.00    | 21.00   |
| Male   | 55  | 12.38| 3.577          | 6.00    | 22.00   |

Table 6 of column 3, it was seen that female students had a better average of metacognitive regulation than that of male students. Female students used a better strategy of problem solving and was more capable in critical thinking and regulate their thinking process than male students [25,26].

This is a number 3 essay test given to students "Mr. Joko is a famous gallon entrepreneur in his village. He has 3 gallon-producing machines. In one week, machine A produces 4 times more gallons than machine B. Machine C produces 400 gallons more than the machine A. Three machines work together and produce 18,400 gallons for one week. If Mr. Joko asks his employees to record the gallons obtained for one month, then how many gallons are produced from each machine for one month?" The following will be described the differences in the activities of metacognitive regulation (planning, monitoring, and evaluation) between female students and male students when completing the number 3 essay test.

The planning is to write down the information that will be used. Both female students and male students have met the indicators of the planning stage, namely students can write down what is known and what is asked about the problem. One answer from female students and male students at the planning stage is shown in figure 1 and figure 2.

**Step 1.** Write down the information of data known from the problem!

Mr. Joko has 3 gallon-producing machines. Machine A produces 4 times more gallons than machine B. Machine C produces 400 gallons more than machine A. Three machines produce 18,400 gallons for one week.

**Step 2:** Write down the information of the data asked from the problem!

How many gallons are produced from each machine for one month?

In the monitoring, male students have not fulfilled the monitoring stage namely students were wrong in changing information that is known to be a mathematical model. This error is caused by students who do not understand the phrase "Machine C produces 400 more gallons of machine A" and less student experience in solving story problems. The less experience a student has in solving problems, he cannot improve the resolution process effectively [6]. This is different from female students because it has fulfilled the monitoring stage. Female students are able to make mathematical models correctly in accordance with what is known and able to complete correctly according to what was asked. One of the answers of female students at the monitoring is shown in figures 3 and figure 5, while answers of male students at the monitoring stage are shown in figures 4 and figure 6.
In the evaluation, male students do not meet the evaluation requirements because students do not do the re-examination that has been done. Conversely, female students re-examine the steps that have been taken correctly to complete the evaluation. By completing the answers that can be done by students to solve the mistakes made can solve the problem correctly. Next One of the answers from female students and male students at the evaluation stage is shown in figure 7 and figure 8.

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4. Conclusion
Based on the results and discussion, it was concluded that there were differences in metacognition between female and male students. In the component of metacognitive knowledge, there is no difference between female students and male students, whereas in the component of metacognitive regulation there is a difference between female and male students. Female students have better average metacognitive regulation than male students.

Students can be encouraged to involve metacognition in the learning process. Here the role of teachers is very important, therefore teachers must know how to empower metacognition during the learning and teaching process. Empowerment is beneficial for students who have difficulty learning mathematics. Teachers must remind students that metacognition is needed to improve academic achievement. One of the empowerments of metacognition that can be done by teachers is by applying cooperative learning models and problem-based learning models.

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