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Mathematical Critical Thinking Ability in Solving HOTS Problems Based on Cognitive Style and Gender

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Abstract

This study aims to identify students' mathematical critical thinking ability in solving HOTS problems based on cognitive styles and gender. It is a descriptive and qualitative study. It used the purposive sampling technique to determine 4 subjects based on the categories of impulsive and reflective cognitive styles covering both male and female students. Data were collected by interviews, documentation, the MFFT test, and the mathematical critical thinking skill test using HOTS questions. The results showed that students who have the impulsive cognitive style could meet the FRISCO indicators in solving HOTS questions. Students with a reflective cognitive style could not meet the indicator of reason as they were unable to provide supporting reasons related to the information found. Female students provided a more detailed, coherent, and clearer explanation in solving HOTS questions compared to male students.

Keywords: mathematical critical thinking ability, HOTS, cognitive style, gender

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INTRODUCTION

Critical thinking is an action in making decisions and collecting information related to the problems faced by the need in finding the truth. Critical thinking is a process of gaining knowledge by accepting and rejecting information by using reasoning before concluding (Abdullah, 2013; Chukwuyenum, 2013; Ramadhani et al., 2020). Students who have critical thinking can analyze arguments so that they can draw appropriate conclusions (Chasanah, 2019). In finding solutions to solving mathematical questions, a student needs to have critical thinking skills. Students with critical thinking skills can come up with various of solutions to problems they face. Effectively developed critical thinking skills can make students superior in solving given problems (Peter, 2012; Rahayu et al., 2018; Syafruddin et al., 2020).

Critical thinking is associated with the assumption that thinking is a potential that exists in every person and should be developed to achieve optimal results. Critical thinking abilities must be developed and guided because they are essential for students (Cahyono, 2017; Maričić et al., 2015). Critical thinking influences the learning quality (Noor, 2019). Chukwuyenum (2013) said that mathematical critical thinking ability can be used to solve daily life problems enabling a person to take reliable and informed decisions, including logical reasoning, explanation, analysis, and re-evaluation of information.

In general, learning mathematics occurs mechanistically using practical formulas without a construction process that will improve the student's critical thinking skills. Therefore, students only rely on formulas to solve mathematical problems and cannot develop mathematical thinking skills. A study by Parameswari et al (2020) found that

students' critical thinking skills are mostly in the low category. This seems to be coherent with Safrida et al (2018) that only 23.33% of students have critical thinking skills. This is because students are shy to ask questions, lack confidence, and only memorize formulas, so they cannot use their critical thinking well in solving a mathematical question.

Mathematical critical thinking can be improved by providing regular practice. This allows students to explore critical thinking skills and implement the others to continue improving problem-solving performance (Chukwuyenum, 2013). Ennis proposes some indicators of mathematical critical thinking skills needed by students in finding solutions to mathematical problems are Focus, Reason, Inferences, Situation, Clarity, and Overview (FRISCO) (Fridanianti, et. al, 2018). These six indicators relate to understanding the problem given to re-examining the solutions.

Higher Order Thinking Skills (HOTS) questions are effective questions to stimulate students' critical thinking skills. The HOTS question links reasoning focusing on higher-order thinking to develop critical thinking, logic, reflective, metacognitive, and creative thinking skills (Surtapuspitariini et al., 2018). Students' critical thinking skills can be enhanced and established by consistently familiarizing them with HOTS questions. In the bloom taxonomy, the HOTS levels are C4 (analyze), C5 (evaluate), and C6 (create). The best performance in solving HOTS questions can improve students' ability (Apino et al., 2016; Heong et al., 2011; Abdullah et al., 2017).

Students have their characteristics in solving the HOTS questions. Differences in learning methods are based on the students' cognitive abilities. Students' cognitive behavior in receiving, analyzing, and responding to an event is a cognitive style (Margunayasa et al., 2019; Noor, 2019; Rahmatina et al., 2014). According to Rozencwajg and Corroyer in Kagan (Fridanianti et al., 2018a), cognitive styles can be categorized into 4, namely reflective, impulsive, low accuracy, and fast accurate. Rahmatina et al (2014) stated that based on the tempo of learning, cognitive styles are divided into two, namely impulsive and reflective cognitive styles. Both styles have their respective advantages and disadvantages in the learning process. Students with a reflective cognitive style will think carefully so that they are slow in answering as they will think deeply in looking for solutions, while students with an impulsive cognitive style do not think carefully and deeply about the question given (Fridanianti et al., 2018a), so they still have a doubt in responding to the question. A previous study by Noor (2019) revealed that students with reflective cognitive styles understand questions compared to students to impulsive cognitive styles.

Students' learning outcomes are not only influenced by cognitive style but also gender differences. There are circumstances where the difference in students' thinking ability in solving a math question is seen based on gender. Male students can explain how to solve questions quite clearly but less coherently and female students can explain how to solve problems clearly and coherently (Kamid et al., 2020). Male and female students have a variety of characteristics in solving mathematical problems. This is by (Hartini et al., 2018; Colomeischi et al., 2015; Lestari et al., 2020) that male and female students show differences in their attitudes toward mathematics learning outcomes.

A previous study by Noor (2019) revealed that students who have the reflective cognitive style have greater critical thinking skills indicators of understanding questions, providing logical reasons, connecting between concepts, and making conclusions. Meanwhile, students with impulsive cognitive styles have better indicators of problem-solving concepts. Hidayanti et al (2020) found that male students cannot find good solutions to solve HOTS questions. This seems to be consistent with Lestari et al (2020) that students' mathematical critical thinking skills in finding solutions to HOTS questions are good in understanding and finding the core problem with their respective strategies, but female students can explain how to solve the problems coherently.

Based on the explanation above, studies on mathematical critical thinking skills in solving HOTS questions based on FRISCO critical thinking indicators and students' reflective

and impulsive cognitive styles as well as a gender are still limited. Thus, this study focuses on analyzing students' critical thinking skills in solving HOTS questions based on cognitive style and gender.

METHOD

This is a descriptive qualitative research is to assess students' mathematical critical thinking skills in solving HOTS questions based on cognitive style and gender. It was conducted in three schools consisting of two state senior high schools in Jakarta and one state senior high school in Bekasi. The population was class XI students consisting of 107 students. This study involved 4 students as subjects determined using the purposive sampling technique.

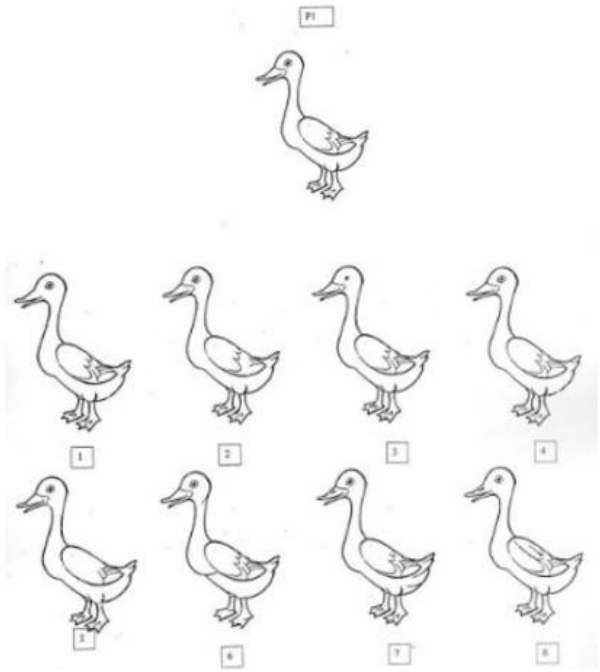

Figure 1. Samples of Matching Familiar Figure Test (MFFT)

Data were collected by asking 13 picture questions and 2 experimental questions of the Matching Familiar Figure Test (MFFT) adopted from Warli (2010). The results of the MFFT test were used to determine whether subjects have reflexive or impulsive cognitive styles. Then, students took the available tests to solve 3 HOTS questions of linear programming material, and then the results were reviewed on the basis of the students' mathematical critical thinking ability indicators of Focus, Reason, Inference, Situation, Clarity, and Overview (FRISCO). The selection of 4 students was based on the category of reflective and impulsive cognitive styles in which each style consisted of female and male students. The analysis of the MFFT test and mathematical critical thinking was continued with interviews. This study used semi-structured interviews to identify HOTS questions completed by students defined as a mathematical critical thinking skills indicators.

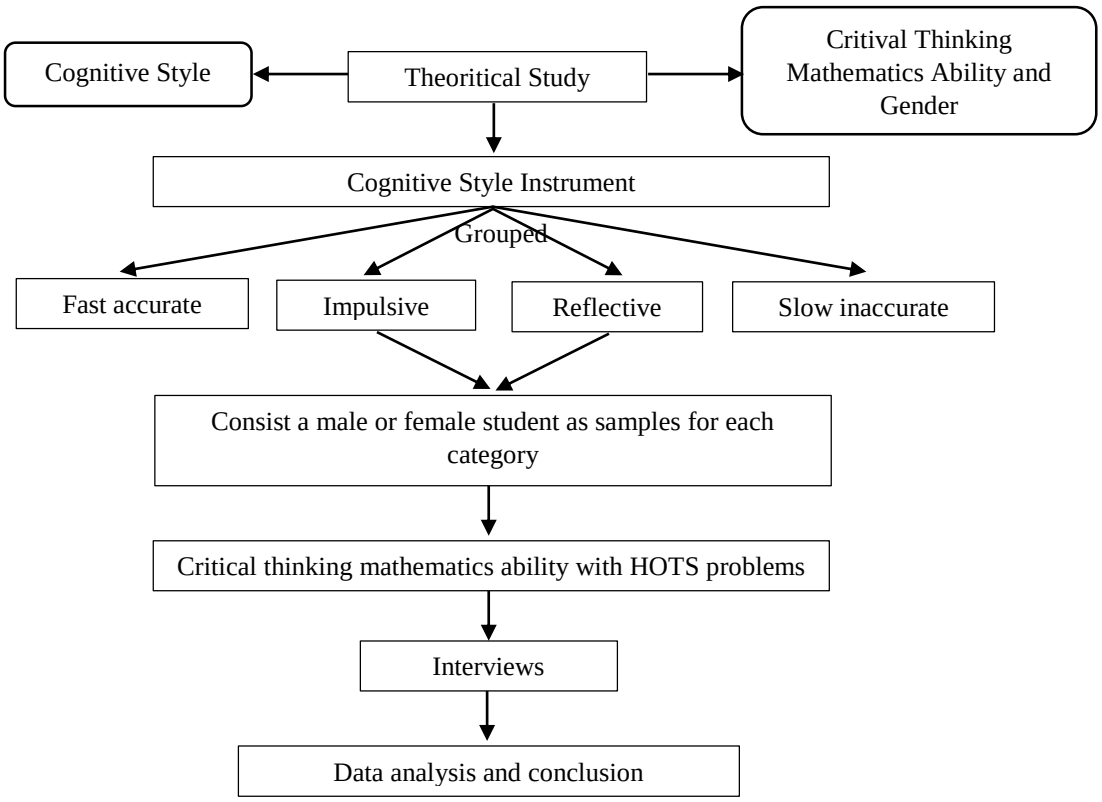

Figure 2. Research Flow

Referring to the figure above, statistical analyses were performed by reviewing findings using HOTS questions but then conducting interviews. Information were analysed from of the findings of tests and interviews. Data were analyzed through data reduction, data presentation, and conclusion drawing. The validity of the data was checked through triangulation techniques to check the results of the mathematical critical thinking ability test by conducting interviews to recheck the results of data collection.

RESULTS AND DISCUSSION

The subject of this study was determined based on the MFFT test results with the category of impulsive and reflective cognitive style from the students' answers based on the time required in answering the for the first time and the frequency of answers until finding the correct answer have been used to determine correct answer. The time and frequency were then calculated to get the median. The students were grouped into each type of cognitive style based on the median value.

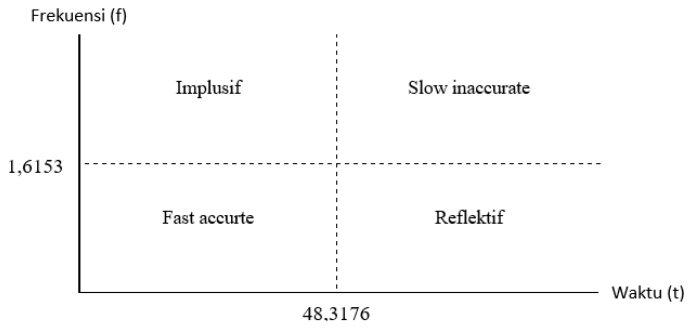

Figure 3. Cognitive Style Grouping into Reflective and Impulsive

According to the result obtained of the graph above, the impulsive cognitive style was determined on the average time (t) of < 48.3176 and the average frequency (f) of > 1.6153. Meanwhile, the reflective cognitive style was determined based on the average acquisition time (t) of > 48.3176 and the average frequency (f) of < 1.6153. Then four students were selected as subjects consisting of two male and female students with the impulsive cognitive style and two male and female students with reflective cognitive styles. The selected subjects are listed in the following table.

Tabel 1. Subjects of the Study

Name	Gender		Cognitive style		Time (seconds)	Frequency
	Male	Female	Impulsive	Reflective		
IP		√	√		392.19	22
IL	√		√		462	23
RP		√		√	1280	20
RL	√			√	990.29	17

Based on Table 1, concerning the time of work, students who have the impulsive cognitive style could work faster than students who have the reflective cognitive style. This is in line with previous studies (Fridanianti et al., 2018; Rahayu et al., 2018) that students with an impulsive cognitive style are slower in answering questions than students with a reflective cognitive style. Therefore, it can be said that students with reflective-impulsive cognitive styles have different attitudes, responses, and accuracy in solving questions when viewed from time off work.

In terms of cognitive style based on gender differences, there was no fundamental difference in the results of the MFFT test obtained. In terms of the ability to find answers to the question, male and female students did not show a difference in learning outcomes (Murtafiah et al., 2018; Stoet et al., 2013). The subject of the study was determined derived from the results of the MFT test. Then, after that, HOTS questions concerning to linear programming materials were used to assess the subjects' mathematical critical thinking skills.

The results of the HOTS questions test were analyzed based on indicators of mathematical critical thinking skills of Focus, Reason, Inference, Situation, Clarity, and Overview (FRISCO). Focus relates to understanding the given problem and reason relates to providing supporting reasons for solving problems. Then, inference relates to drawing acceptable conclusions in solving problems and situation relates to connecting a concept in solving problems. Clarity relates to explaining how to solve problems and overview relates to re-examining the answer made.

Mathematical Critical Thinking Skills of Students Who Have the Impulsive Cognitive Style

The triangulation was checked by conducting interviews with the subjects, IP and IL, related to mathematical critical thinking skills. In terms of focus indicators, IP and IL could examine the problems in the questions. However, IP could write down information from the questions in detail and clearly, while IL wrote information using his sentences and this subject missed some information.

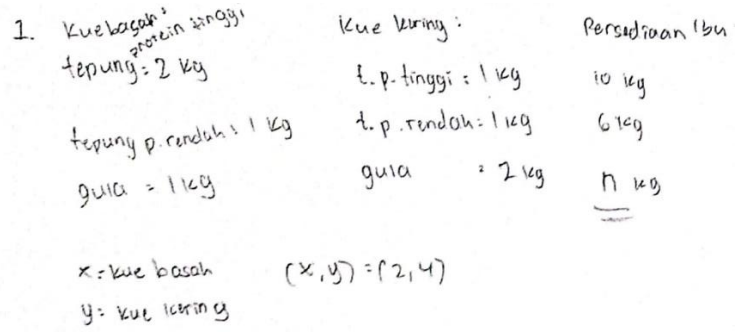

Figure 4. IL's Answer is based on the Focus Indicator

Based on the figure above, IL did not write down information related to the advantages of wet cake dough and pastries listed in the question. The results of the interviews showed that P could describe the problems found well and orderly. In terms of the reason indicator, IP could include support by identifying information, while IL could not provide a valid reason on how to solve the HOTS questions. It can be seen from the results of the interview, "*Yes, because it is known (2.4), then just substitute it directly into the equation*". That's also apparent in question number 3, namely the C6 (create) in which IL could not identify the information in the equation in the graph.

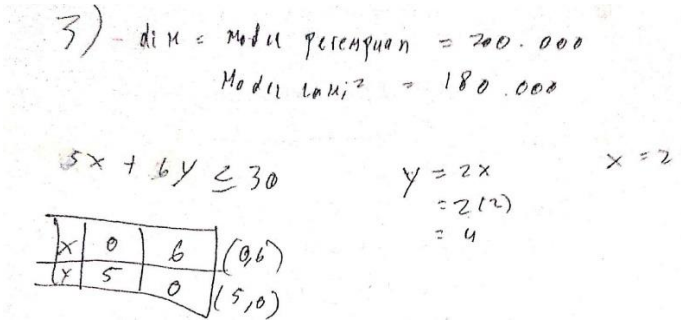

Figure 5. IP's Answer based on the Reason Indicator

IP could perform identification by making an equation based on the information displayed on the graph. In the inferences indicator, IP and IL collected and drew information to determine conclusions in solving HOTS questions. However, IL could explain well in determining the solution to the question. In the situation indicator, IP could not relate the concept of the question based on the information even though IP can solve the problem using the information obtained. Meanwhile, IL can relate the concept of the problem based on all the information that fits the problem.

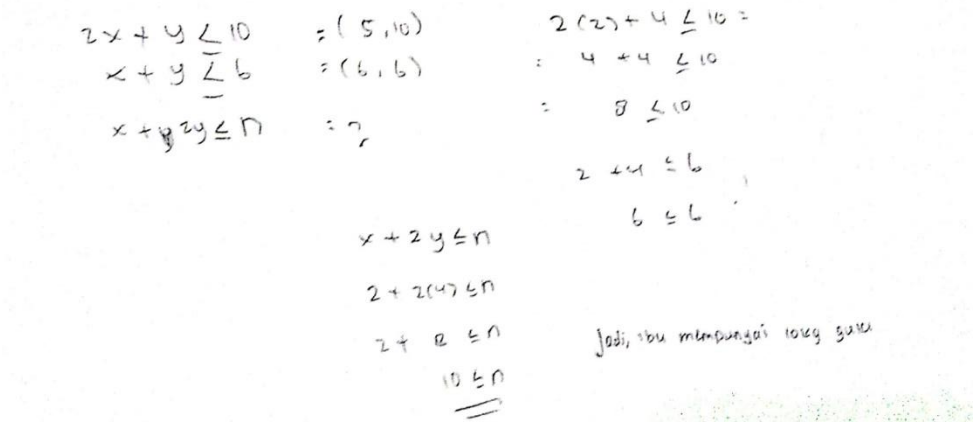

Figure 6. IL's Answer is based on the Situation Indicator

Based on the mathematical model obtained, IL did not make a graph of the equation. IL directly made assumptions by substituting the point (2,4) into the three equations. In the clarity indicator, IP could solve the question based on the information obtained. Meanwhile, IL could solve the question even without digging in-depth information. Besides, IL could not explain coherently in solving the problem.

In the overview indicator, based on the results of interviews, IP could re-check the results of the answers obtained from the initial process to the end. However, IL did not reevaluate the answers. IL stated that the results obtained were correct.

Moreover, female students could describe in detail, coherently, and the information obtained in solving HOTS questions compared to male students who explained uncoordinatedly. Male students could not describe the question in detail as female students did (Cahyono, 2017; Stoet et al., 2013). Female students with the impulsive cognitive style could provide precise and clear answers, while male students could not fulfill the critical thinking indicators and could not give correct answers. Students with the impulsive cognitive style were less thorough in solving questions (Fridanianti et al., 2018b; Noor, 2019). This is by the results of the analysis that it was only male students with cognitive-impulsive style who could solve problems properly by the appropriate problem-solving steps.

Mathematical Critical Thinking Skills of Students Who Have the Reflective Cognitive Style

Based on the RP and RL's answers to the questions, the triangulation was carried out by conducting interviews. RP and RL had an impulsive cognitive style. In the analysis based on critical thinking indicators, especially the focus indicator, RP could write down all the appropriate information in the question correctly, while RL could only write some information with some incorrect statements in the information given.

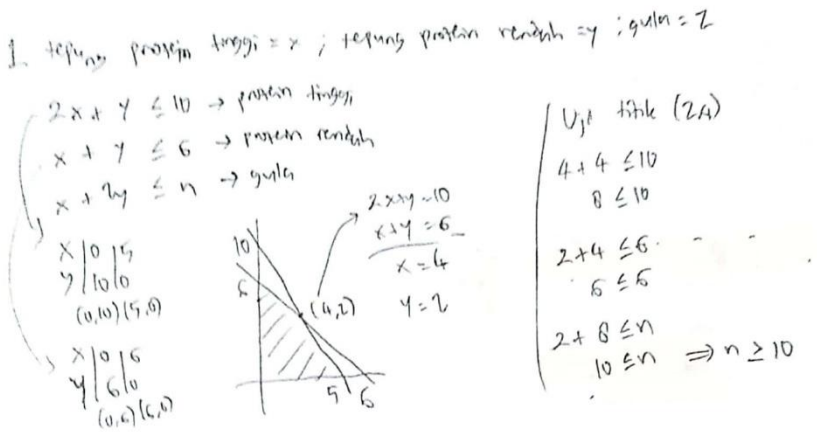

Figure 7. RL's Answer is based on the Focus Indicator

The example provided by RL did not match the information contained in the question. Therefore, the RL was not competent in understanding the problem on the question properly. In the reason indicator, RP and RL could provide supporting reasons related to the questions based on the information found, even though in the writing stage the information obtained by RL was incorrect. In the inferences indicator, RP and RL could collect and draw information to determine the answer, but RP wrote an inappropriate method for getting the answer.

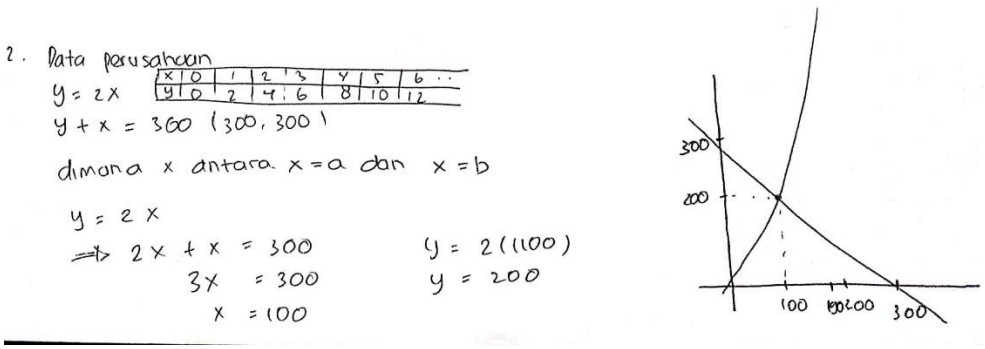

Figure 8. RP's Answer is based on the Inference Indicator

RP could not use the obtained information to solve HOTS questions at the C5 (evaluate) level. Referring to the interview results, RP stated that he was doubted in determining how to solve it. In the situation indicator, RP could not relate the concept of the problem based on the available information, while RL could use all the available information by relating the concept to a mathematical problem.

In the clarity indicator, RP and RL could solve the problems given. However, RL did not describe in detail the answers. Besides, RL could not explain in detail how to solve the question as seen in the answers in solving HOTS question number 3, which is at level C6 (create).

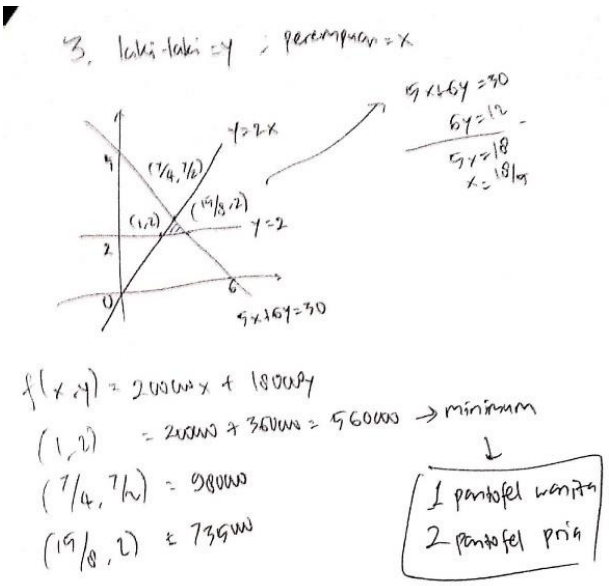

Figure 9. RL's Answer is based on the Clarity Indicator

Figure 9 shows that RL immediately wrote down the results of the calculations obtained without describing the numbers obtained. Based on the results of the interview, RL could not explain in detail and coherently how the answers were found. In the overview indicator, RP and RL did not re-check the answers. This is based on the interview results that according to students who have the reflective cognitive style, the provided time is short so students need more time to accurately determine solutions based on the information obtained as students (Margunayasa et al., 2019; Rahayu et al., 2018).

Based on the critical thinking test results, female students could describe in detail, coherently, and based on the information obtained in solving HOTS questions compared to male students. In this case, female and male students have differences in the process of solving HOTS questions (Cahyono, 2017; Colomeischi et al., 2015). Besides, according to

Setyawati et al. (2017), there were differences in students' abilities based on gender in finding solutions to the question given. Thus, female students with impulsive cognitive style can meet the criteria for critical thinking indicators by submitting answers correctly and clearly, while male students cannot meet critical thinking indicators and cannot give answers correctly.

CONCLUSION

Derived from the findings of the research, critical thinking skills are predicated on the FRISCO indicator in solving HOTS questions. In the focus indicator, female students who have impulsive and reflective styles can describe and convey information from the questions better than male students. In the reason indicator, students who have the impulsive cognitive style can identify problems by providing supporting reasons than those who have the reflective cognitive style. In the inferences stage, students who have the impulsive and reflective cognitive style can gather information to conclude, but the male students cannot give proper explanations. In the situation indicator, male students are better at relating the concept of the question based on the information found compared to female students. In the clarity indicator, male students cannot explain coherently and clearly in solving HOTS questions as female students. At the overview stage, students with the impulsive cognitive style can re-examine the answers obtained compared to students who have the reflective cognitive style.

RECOMMENDATION

Based on the findings of the research, it's also expected to consider students' cognitive style and gender in mathematical learning. It also is important to develop students' mathematical critical thinking skills by providing HOTS questions with the help of appropriate learning models in teaching activities.

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