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## REFLECTIVE THINKING CHARACTERISTICS: A STUDY IN THE PROFICIENT MATHEMATICS PROSPECTIVE TEACHERS

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### ABSTRACT

Reflective thinking begins with repeated confusion and evaluation to solve a problem. There are four aspects to reflective thinking, namely techniques, monitoring, insight, and conceptualization. However, the problem-solvers' reflective thinking characteristics in mathematical problems have not been discovered. The study describes the reflective thinking characteristics of proficient mathematics prospective teachers based on four aspects. The qualitative research was conducted at Universitas Muhammadiyah Surakarta with a total of 64 reflective thinkers. Data collected by test, observation sheets, and interview methods. The tests were administered twice. The instruments developed has been through the validation process and declared valid. Data analyzed through the stages of reduction, presentation, and verification. We successfully conclude that proficient mathematics prospective teachers have complete and consistent reflective thinking characteristics. Further research can be focused on the characteristics of reflective thinking based on another aspect.

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## 1. INTRODUCTION

Reflective thinking has been explored by several experts (Dewey, 1933; Habermas, 2015; Schön, 1992). They stated that reflective thinking is a mental activity that employs knowledge and experience in solving a problem. Furthermore, reflective thinking begins with the confusion of the problem solver and attempts to solve the problem (Rodgers, 2002). Suharna (2018) has explored individual differences in overcoming confusion during reflective thinking to solve mathematical problems. Prospective mathematics teachers with productive reflective thinking categories overcome confusion by using various ways of solving problems. Prospective mathematics teachers with the category of reflective thinking connectively overcome confusion by connecting all mathematical concepts, principles, and processes related to mathematical problems or solutions. Prospective mathematics teachers

with the category of reflective thinking overcome confusion by matching solutions with related concepts.

Zehavi & Mann (2005) stated that there are four aspects of reflective thinking, namely techniques, monitoring, insight, and conceptualization. Aspects of techniques are individual activities in selecting effective and efficient strategies to solve problems. Monitoring is the activity of re-monitoring the steps and solutions of mathematical problems encountered. Insight is a condition where an individual uses his ingenuity and emotions in solving problems. This aspect involves how much motivation and persistence of individuals to keep trying to solve problems when experiencing confusion. Conceptualization is an individual activity involving his ability to connect several concepts and meanings that have been understood to make the right decision.

The authors have reviewed several studies related to reflective thinking. First, researches that focus on developing instruments to measure reflective thinking are reflective thinking scale, questionnaire, rubric for evaluating reflective thinking/REPORT, and a set of mathematical problem (Agustan et al., 2017; Basol & Gencel, 2013; Sezer, 2008). Second, research described reflection abstraction in solving mathematical problems (Djasuli et al., 2017). The research concluded that students' strategies of problem-solving are not directly proportional to their level of reflective abstraction. Next, researches that discovered the role of reflective thinking into problem solvers' performance (Aytekin et al., 2018; Hong & Choi, 2011; Mojžišová & Pócsová, 2019; Nigrini & Karstens, 2019; Thompson & Thompson, 2018; Tutticci et al., 2018). They stated that problem solvers that employ reflective thinking make the fewest mistakes, make the right decisions, and have impressive accomplishments. Besides, research by Hidajat et al. (2019) concluded that confusion occurs due to the misunderstanding and failure factor in generating new ideas and strategies. Based on the review, there is no research focus on the development of reflective thinking indicators and characteristics in mathematical problem solving, especially on analytical geometry content.

In the last 2019, researchers had conducted preliminary research to develop reflective thinking indicators based on four aspects. It was a qualitative research employe test, observation, and interview method to collect the data. Indicators that have been concluded in each aspect are presented in Table 1.

**Table 1.** Description of aspects and indicators of reflective thinking

Aspects	Indicators	Code
Techniques	1. Understanding given informations	T1
	2. Understanding the questions	T2
	3. Filtrerring necessary informations	T3
	4. Selecting an effective and efficient solution	T4
	5. Understanding hot to get information	T5
Monitoring	1. Monitoring the steps of solution	M1
	2. Monitoring wether the answers are correct or not	M2
	3. Devising strategies for problem solving	M3
	4. Making a consideration before making decision	M4
Insight	1. Feeling enthusiastic for solving problems	I1
	2. Being ready to correct wrong answers	I2

Aspects	Indicators	Code
	3. Feeling responsible for the solutions written	I3
	4. Writing down the answers clearly	I4
	5. Understanding how to prevent difficulties	I5
Conceptualization	1. Thinking about strategies for solving problems	C1
	2. Thinking about an alternative way for solving problem	C2
	3. Relating the questions with relevant problems	C3
	4. Relating concepts for problem solving	C4
	5. Understanding the reason for every solution	C5

The research’s objective is discovering the characteristics of reflective thinking of prospective mathematics teachers with high mathematical abilities in solving analytic geometry problems in aspects of techniques, monitoring, insight, and conceptualization based on indicators that have been developed. The characteristics of reflective thinking are seen from the tendency of changing patterns of indicators shown by the subject when solving the first and second problems.

## 2. METHOD

### 2.1. Type

The qualitative research describes how the reflective thinking characteristics of proficient mathematics prospective teachers in solving analytical geometry problems. The data described all the facts of data without manipulation so this study employee a descriptive design (Sagala et al., 2019).

### 2.2. Participants

The subjects in this study were 64 mathematics prospective teachers in Mathematics Education Study Program at Universitas Muhammadiyah Surakarta - Indonesia. They have taken analytical geometry courses, employee reflective thinking in problem-solving, have good communication skills when solving problems with think-aloud techniques, and have mathematical abilities in the high category (proficient). Determination of the tiered categories of mathematical abilities of prospective mathematics teachers in proficient, sufficient, and novice categories based on standard deviations and the mean. The boundaries reported in [Table 2](#).

**Table 2.** The boundaries of mathematical ability (MA)

Category	Boundaries	Number
Proficient	$MA \geq 63,75$	17
Sufficient	$38,33 \leq MA < 63,75$	24
Novice	$MA < 38,33$	23

The purposive sampling (Putranta & Jumadi, 2019) is employed because researchers only focus on reflective thinker subjects. In this paper, the result of two participants (namely

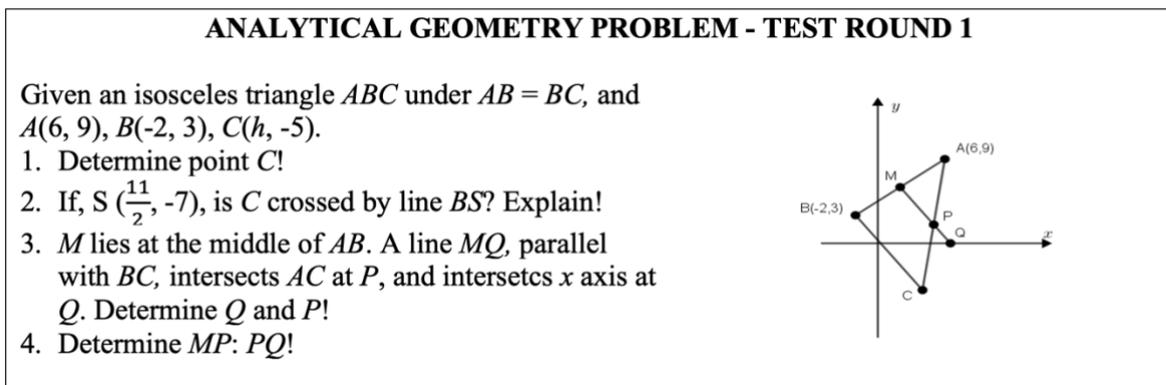
subject S-1 and S-2) are explained because data already represent the whole data in proficient categories.

### 2.3. Instruments

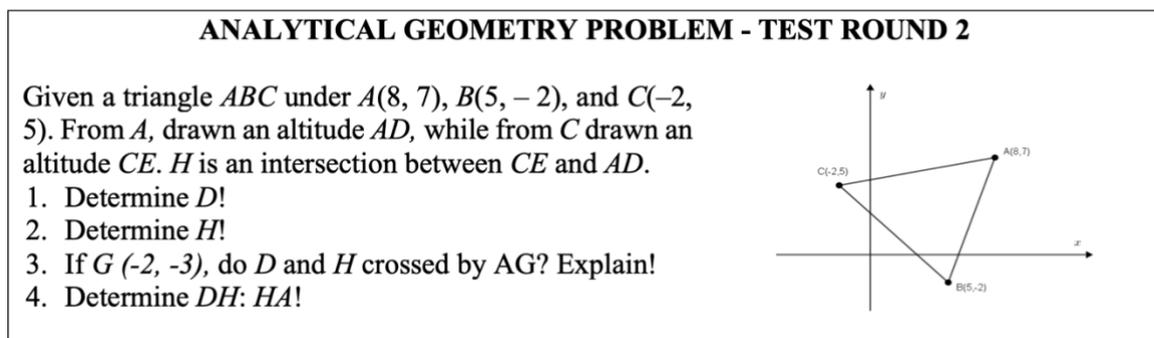
The instruments employed in this study are tests administered for twice, the observation sheet, and interview guidelines. The indicators of test and observation refer to reflective thinking indicators reported in Table 1. All instruments have been through the validation process and declared valid. The number of validators is three persons. The experts in mathematics, mathematics education, and educational qualitative research. The suggestions from the validator are editorial improvements to the problem. They asked for an adjustment in mathematical vocabulary so that there were not multi-interpretations.

### 2.4. Data Collection Method

The data explored based on subjects' answer sheets of problem-solving results, video recording when the subjects solve the problem, interviews, and observation sheets. Test instruments are used to determine the characteristics of reflective thinking in solving problems. The problem is presented in Figure 1 and Figure 2. Participants employ a think-aloud method in solving analytical geometry problem. It is a method for expressing aloud the processes and symptoms of thinking that arise in cognitive (Charters, 2003). The think-aloud method is very suitable to see the thought process of research subjects.



**Figure 1.** Analytical geometry problem for test round 1



**Figure 2.** Analytical geometry problem for test round 2

## 2.5. Data Analysis

Data analysis through the stage of data reduction, data presentation, and concluding. The complete research procedure presented in Figure 3.

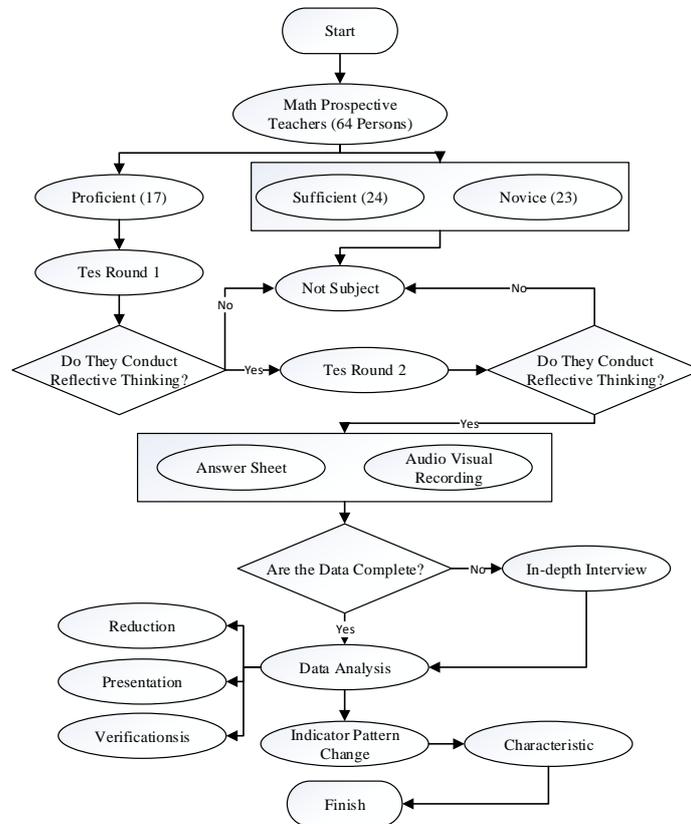


Figure 3. Research procedure

## 3. RESULTS AND DISCUSSION

### 3.1. Results

#### 3.1.1. Subject S-1: Data exposure and analysis

Looking at the S-1 answer sheets, think-aloud transcripts, observation sheet, interview transcripts, and analysis, the S-1 reflective thinking change patterns in terms of test round 1 can be described as follows. In solving test round 1, S-1 gave rise to indicators T1, T2, T3, and T4. This is indicated by S-1 reading the problem repeatedly, rewriting given information, writing questions, and drawing back information to facilitate understanding. Indicator T5 marked with S-1 determines the length of the segment AB first, then the length of the segment BC is equal to AB. Indicators C2, M2, and I3 appear when S-1 thinking about other solutions in determining the value of h. S-1 experienced confusion so he monitored whether the answer correct or not. Besides, this step taken by S-1 to provide confidence in the answer. S-1 performs indicator M1. This can be seen when S-1 monitors the completion steps from Question 1 that has been written.

In solving Question 2, S-1 starts with confusion to investigate whether point C is passed by line BS. However, S-1 seemed enthusiastic about the confusion experienced. This indicates that S-1 performs indicators of I1 and I2. S-1 realizes that it takes several steps before determining the equation of line BS. For this, S-1 draws a plan and consideration to

answer Question 2. His plan is determining the equation of line BS and substituting point C into the equation of line BS. An alternative plan is investigating whether line BS and line BC are coincided. In determining the equation of line BS, he knows how to avoid difficulties. It by simplifying the equations of line BS and BC. His answer in investigating whether line BS crosses C is written very clearly and systematically. This indicates that S-1 performs indicators M3, I4, I5, and M4.

In solving Question 3 and Question 4, S-1 performs indicators C1, C3, C4, and C5. This is marked by S-1 thinking about the way that will be employed before answering questions, relating the results of the questions Question 1 and Question 2 with the next two questions to be answered, and relating some mathematical concepts. He experienced confusion for several times, but he was able to demonstrate mastery of the material so that it knows every reason for the answers written.

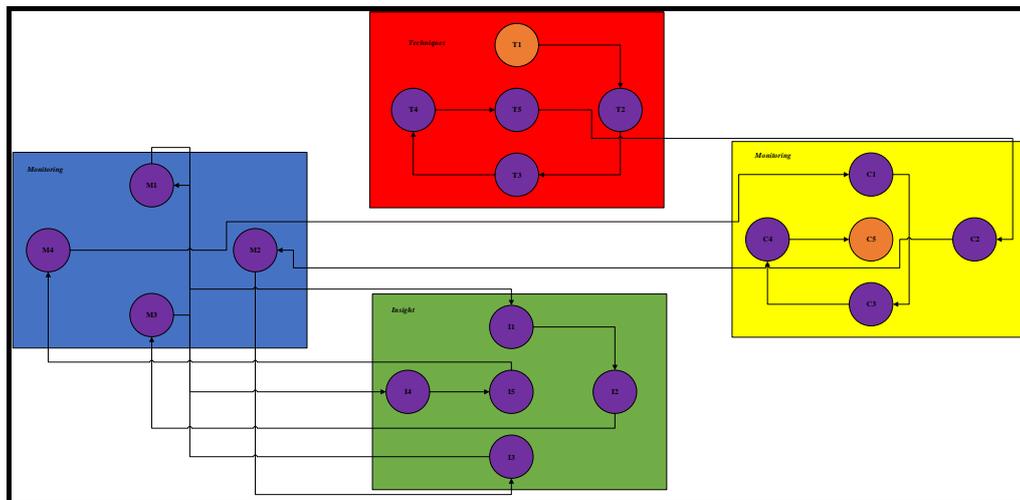
Looking at the S-1 answer sheets, think-aloud transcripts, observation sheet, interview transcripts, and analysis, the S-1 reflective thinking change patterns in terms of test 2 can be described as follows. In solving test round 2, S-1 raises the indicators T1, T2, T3, and T4. This is indicated by S-1 reading the problem repeatedly, rewriting given information, writing questions, and drawing back given information to facilitate understanding. Indicator T5 marked with S-1 determines the gradient of CB, gradients of AD, and equation line AD first before obtaining the coordinates of point D. Indicators C2, M2, and I3 appear when S-1 uses two methods in determining gradient CB. He experienced confusion so he employed more than one way to monitor whether the answer correct or not. Moreover, this step was taken to provide confidence in the answer. S-1 performs indicator M1. This can be seen when S-1 monitors the completion steps from Question 1 that has been written.

In solving Question 2, S-1 starts with an error that confuses. However, he seemed enthusiastic and willing to correct the mistakes. This indicates that he performs indicators of I1 and I2. S-1 realizes that it takes several steps before determining the coordinates H. For that, S-1 draws up a plan and takes into consideration to answer Question 2. His plan to solve Question 2 is determining gradient AB, determining gradient CE, determining the equation of line CE, intersection line CE and line AD should be H. In determining H, he knows how to avoid difficulties. The method employed was substituting equations line CE to the equation line AD. The solution in determining the coordinates of the H is written very clearly and systematically. This indicates that S-1 performs indicators M3, I4, I5, and M4.

In solving Question 3 and Question 4, S-1 performs indicators C1, C3, C4, and C5. This is marked by S-1 thinking about the way that will be employed before answering questions, relating the results of Question 1 and Question 2 with the next two questions to be answered. He also related some mathematical concepts for solving the problem. S-1 experienced confusion several times but he was able to demonstrate mastery of the material so that it knows every reason for the answers written.

In solving analytical geometry test both round 1 and 2, S-1 conducted 19 indicators of reflective thinking i.e 5 indicators on the technique aspects, 4 indicators on the monitoring aspects, 5 indicators on the insight aspects, and 5 indicators on the conceptualization aspects. In Question 1, he performs indicators T1, T2, T3, T4, T5, C2, M2, I3, M1, in Question 2 he performs indicators I1, I2, M3, I4, I5, M4, and in Question 3 and Question 4, he performs indicators C1, C3, C4, and C5. The changing pattern of indicator in solving analytical geometry test both round 1 and 2 presented in [Figure 4](#). The red, blue, green, and yellow squares successively illustrate aspects of techniques, monitoring, insight, and conceptualization. The circle in each box illustrates the indicators of reflective thinking in each aspect. The direction of the arrow indicates the order of change of each indicator. The

changing pattern starts from the orange circle on the red square and ends on the orange circle on the yellow square.



**Figure 4.** The Reflective Thinking Change Pattern of S-1

Figure 4 describes the sequence of reflective thinking change patterns of S-1 in solving both tests. The sequence starts from the orange circle in the red square and ends in the orange circle in the yellow box. The sequence of indicators conducted by S-1 is T1, T2, T3, T4, T5, C2, M2, I3, M1, I1, I2, M3, I4, I5, M4, C1, C3, C4, and C5 (Symbol Description for Figure 4 can be seen in Table 3).

### 3.1.2. Subject S-2: Data exposure and analysis

Looking at the S-2 answer sheets, think-aloud transcripts, observation sheet, interview transcripts, and analysis, the S-1 reflective thinking change patterns in terms of test round 1 can be described as follows. In solving test round 1, S-2 raises the indicators T1, T2, T3, and T4. This is indicated by S-1 reading the problem repeatedly, rewriting given information, writing questions, determining the length of the segment AB first, then the length of the segment BC equal to the AB. Indicator T5 marked by drawing back given information to ascertain the coordinate of point C.

Indicators M3, M4, C1, M1, and M2 appear when she draws up various settlement plans to solve Question 2. She makes various considerations to overcome confusion. The confusion she experienced is making errors in calculating, so she re-monitored the completion steps and written solutions. S-2 performs indicators of I2, I3, and I1. This can be seen when S-2 is willing to correct mistakes with full responsibility and enthusiasm.

In solving Question 3, she thought about how to avoid the difficulty in determining M. The solution proposed clearly and systematically. This indicates she performs indicators I5 and I4. S-2 realizes that there is more than one solution to solve Question 4. However, she prefers to employ one method and does not confirm the answer by another method because of confidence about the answer. During solving Question 4, S-2 related questions and concepts she has so that he knows every reason for the solution. This indicates that S-2 performs indicators C2, C3, C4, and C5.

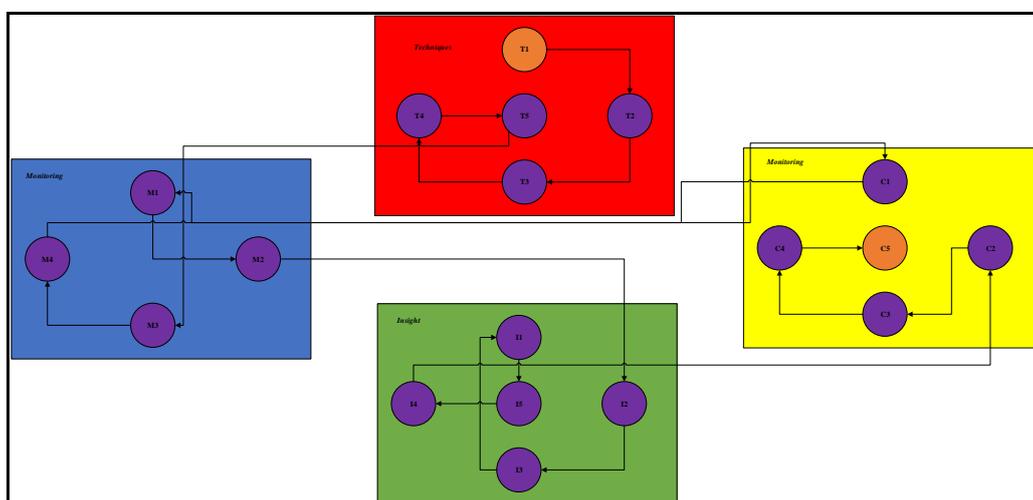
Looking at the S-2 answer sheets, think-aloud transcripts, observation sheet, interview transcripts, and analysis, the S-1 reflective thinking change patterns in term of test round 2 can be described as follows. In solving test round 2, she performs the indicators of T1, T2, T3, T4, and T5. This is marked by reading the problem repeatedly, rewriting given

information, writing questions, and drawing back information on the problem to facilitate understanding.

Indicators M3, M4, C1, M1, and M2 appear when she prepares various settlement plans to solve Question 2. She experienced confusion when writing symbols so that she monitors the completion steps and solution. This step conducted to provide confidence in the solution. S-2 performs indicators of I2, I3, and I1. This can be seen when S-2 is willing to correct mistakes with full responsibility and enthusiasm.

In solving Question 3, S-2 thought of how to prevent the difficulty. In investigating whether D and H crossed by line AG, she substituted D and H into equation AG. The solution written by her seems clear and systematic. This indicates S-2 performs indicators I5 and I4. In solving Question 4, S-2 performs indicators C2, C3, C4, and C5. This is indicated by S-2 thinking about various ways of solving to answer Question 4. She also related Question 1 and Question 2 in addressing the next two questions. She experienced confusion several times, but She was able to show mastery of the material. Moreover, she knows every reason for the solution.

In solving analytical geometry test both round 1 and 2, S-2 conducted 19 indicators of reflective thinking i.e 5 indicators on the technical aspects, 4 indicators on the monitoring aspects, 5 indicators on the insight aspects, and 5 indicators on the conceptualization aspects. In Questions 1, she performs indicators T1, T2, T3, T4, and T5. In Question 2, S-2 performs indicators M3, M4, C1, M1, M2, I2, I3, and I1. In Question 3, she performs indicators I5 and I4. In Question 4 S-2 performs indicators C2, C3, C4, and C5. The changing pattern of indicator in solving analytical geometry test both round 1 and 2 presented in Figure 5. The red, blue, green, and yellow squares successively illustrate aspects of techniques, monitoring, insight, and conceptualization. The circle in each box illustrates the indicators of reflective thinking in each aspect. The direction of the arrow indicates the order of change of each indicator. The changing pattern starts from the orange circle on the red square and ends on the orange circle on the yellow square.



**Figure 5.** The Reflective Thinking Change Pattern of S-2

Figure 5 describes the sequence of reflective thinking change patterns of S-2 in solving both tests. The sequence starts from the orange circle in the red square and ends in the orange circle in the yellow box. The sequence of indicators conducted by S-2 is T1, T2, T3, T4, T5, M3, M4, C1, M1, M2, I2, I3, I1, I5, I4, C2, C3, C4, and C5. (Symbol Description for Figure 5 can be seen in Table 3).

**Table 3.** Symbol Description for [Figure 4](#) and [Figure 5](#)

Symbol	Description
	Techniques Aspect
	Monitoring Aspect
	Insight Aspect
	Conceptualization Aspect
	The beginning and end of reflective thinking indicator
	Indicator performed
	Indicator not performed
	The direction of change pattern

### 3.2. Discussion

The data exposure and analysis show that both S-1 and S-2 perform all the reflective thinking indicators. In both tests, S-1 shows the change patterns are T1, T2, T3, T4, T5, C2, M2, I3, M1, I1, I2, M3, I4, I5, M4, C1, C3, C4, and C5. Whereas, S-2 shows patterns of T1, T2, T3, T4, T5, M3, M4, C1, M1, M2, I2, I3, I1, I5, I4, C2, C3, C4, and C5. Although both proficient mathematics prospective teachers show different change patterns, there are interesting findings that can be revealed. They show a complete and consistent change in both tests round 1 and 2. Complete characteristic means the proficient prospective mathematics teachers perform all indicators of reflective thinking on both tests. The consistent characteristic means that the proficient prospective mathematics teachers show the same change pattern between test round 1 and 2. It is relevant to Rodgers (2002) stated reflection is a systematic, rigorous, disciplined way of thinking, with its roots in scientific inquiry. Reflective thinking is a way of thinking that is systematic, thorough, and disciplined based on the reasons for scientific discovery. Sarid (2012) argued that a logical structure is consistent with a systematic thought process. The logical structure is consistent with the process of systematic thinking. The characteristic of complete and consistent reflective thinking described as structured and systematic reflective thinking.

Complete and consistent reflective thinking performed by proficient prospective mathematics teachers employ a metacognitive process. In employing reflective thinking processes, aspects that appear represent aspects of the metacognitive process. The aspects of metacognitive thinking are awareness, evaluation, and regulation (Magiera & Zawojewski, 2011).

Awareness is a situation where an individual is aware of the information he is thinking about (Baltaci et al., 2016; Purnomo et al., 2017). This is synonymous with confusion and techniques aspect as a characteristic of the emergence of reflective thinking, where the confusion is a symptom of perplexity that appears as the beginning of the reflective thinking process accompanied by individual awareness to overcome the confusion that arises (Suharna et al., 2020).

Evaluation aspect is a condition where individuals conduct monitoring, plan formulation, and consideration for making decisions in problem-solving (Callan et al., 2016; Maharani et al., 2019). The evaluation aspect of metacognitive thinking is identical to the

monitoring aspect of reflective thinking namely re-monitoring of information that has been thought to provide confidence in individuals as problem solvers (Zehavi & Mann, 2005).

Regulation is a condition where the individual sets the goal of the solution to the problem at hand where this activity arises after an evaluation (Kuzle, 2013; Purnomo & Bektı, 2017). The regulatory aspect of the metacognitive process is identical to the aspect of insight and conceptualization in the reflective thinking process. Insight can be an individual effort as a problem solver to overcome emerging confusion or awareness (Zehavi & Mann, 2005). Moreover, conceptualization described as an effort in relating among mathematics concepts (Sa'dijah et al., 2020) by employing abstraction (Djasuli et al., 2017) or visualization (Zayyadi et al., 2020).

Research focuses on thinking characteristics for problem-solving conducted by Purnomo et al. (2017). The research focused on students' metacognition characteristics in solving a calculus problem. The qualitative research discovered three characteristics among others: complete with the order, complete with no the order, and incomplete.

#### **4. CONCLUSION**

We successfully concluded that proficient prospective mathematics teachers have complete and consistent reflective thinking characteristics. Complete characteristic means the prospective mathematics teacher performs all indicators of reflective thinking on both tests. The consistent characteristic means that the proficient prospective mathematics teachers show the same change pattern between test round 1 and test round 2.

The characteristics of reflective thinking that are complete and consistent performed by proficient prospective mathematics teachers on both tests showing the sequence of understanding given pieces of information, understanding the questions, filtering necessary pieces of information, selecting an effective and efficient solution, understanding how to get information, thinking about an alternative way for solving a problem, monitoring whether the answers are correct or not, feeling responsible for the solutions written, monitoring the steps of the solution, feeling enthusiastic for solving problems, being ready to correct wrong answers, devising strategies for problem-solving, writing down the answers clearly, understanding how to prevent difficulties, making a consideration before making a decision, thinking about strategies for solving problems, relating the questions with relevant problems, relating concepts for problem-solving, and understanding the reason for every solution.

As for the other sequences shown by proficient prospective mathematics teachers on the tests round 1 and 2, namely understanding given pieces of information, understanding the questions, filtering necessary pieces of information, selecting an effective and efficient solution, understanding how to get information, devising strategies for problem-solving, making a consideration before making a decision, thinking about strategies for solving problems, monitoring the steps of the solution, monitoring whether the answers are correct or not, being ready to correct wrong answers, feeling responsible for the solutions written, feeling enthusiastic for solving problems, understanding how to prevent difficulties, writing down the answers clearly, thinking about an alternative way for solving a problem, relating the questions with relevant problems, relating concepts for problem-solving, understanding the reason for every solution.

The change pattern characteristics observed based on aspects of techniques, monitoring, insight, and conceptualization. Further research can be focused on the characteristics of reflective thinking based on another aspect. Indicators of the study appear in the reflective thinking process in solving analytical geometry problems. There is an opportunity for further research to explore reflective thinking indicators on other contents.

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