ANALYZING STUDENTS' DECISION-MAKING STYLE IN MATHEMATICAL CRITICAL THINKING SKILL BASED ON MATHEMATICAL HABITS OF MIND

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Abstract - The aim of this research is to analyze students' decision-making style in mathematical habits of mind. This research is conducted a senior high school grade XI students in one of the schools in Medan. It is a case study adopting a qualitative approach by using descriptive analysis. The data are collected using test, observation, and interview. It was found that more than half of students' mathematical habits of mind is still low. It is also shown that students' mathematical critical thinking skill is still lacking and most students have behavioral decision-making style. Consequently, students with lower mathematical habits of mind have lower cognitive complexity.

Keywords - Mathematical Critical Thinking, Mathematical Habits of Mind, Decision-Making Style.

I. INTRODUCTION

The aim of education in Indonesia based on Law Number 20 of 2003 on National Education system is to develop the students' potential in order to help them face problems in real life. Mathematics is the body of knowledge and academic discipline that has the essential role in developing the students' potential including their thinking ability. According to Ruseffendi, mathematics is formed by the results of human thinking relating to the idea, process, and reasoning[1]. In the other words, mathematics is a discipline in the scientific development of critical thinking, dynamic, and open-mindedness which are part of the reasoning.

Piaget emphasizes the importance of the development of students' critical thinking as one of the goals of education[2]:

"To create men who are capable of doing new things rather than repeating what the previous generations have already done, and to form minds which can think critically, and verify rather than passively accepting everything offered".

Norris and Ennis says that "critical thinking is reasonable and reflective thinking that is focused on deciding what to believe or do"[3]. Thus, the critical thinking ability does not only include the thinking process but also the decision making process. Ennis, Henri, and Garisson formulate critical thinking as a problem-solving process involving five stages, namely focusing and observing on a question or problem, asking and answering questions for clarification of problem, judging and understanding the situation of the problem, analyzing the problem, making and evaluation decisions or solutions, and finally deciding on an action[4].

Another importance of the critical thinking ability is proposed by Glaser, Primack, and Wilson. They declare that the critical thinking ability would influence directly the individual's potential to advance in applying a piece of information effectively so that every individual can decide the best alternative solution to problems[4].

The term 'decision making' means a cognitive response expressing the way of the decision makers to think and respond to the differences of a situation, so they are able to address a problem[5]. Similarly, Goodyear states;

"It is important to note that decision making is primarily a cognitive process that combines the mental process of perception, action and coming to closure on stimuli. Cognitive style, on the other hand, is the patterning or linking of these thinking processes and coming to closure the presence of ambiguity and uncertainty"[6].

The decision making is the crucial phase in the critical thinking ability as it takes part in all critical thinking process, which are interpretation, analysis, evaluation, inference, and explanation. Al Shra'ah explains that decision making is a tool for training the future leaders for the reason that it can improve their leadership style and capacity[6]. Decision making process will lead students to be successful in the future since it is considered as the process of choosing the best alternative for achieving their goals in real life.

Rowe and Richard express decision making in four styles, namely directive, analytical, conceptual, and behavioral[5]. Every style can describe students' thinking characteristic so its classification will aid teacher to comprehend their way of thinking. Moreover, teacher can help and train them in order to change their thinking way be a high cognitive complexity. By having a high cognitive complexity, they will can understand the world in more complex ways rather than those with less cognitive complexity[7].

Based on the research in 2017, it is found that students' who are on the lower cognitive complexity have low critical thinking ability[8]. Sharadgah indicates that it can happen because the critical thinking ability of students has not been optimal

because they do not take the meaning out of the learning experience[9]. As a result, their ability in constructing the mathematical concept is less successful. Furthermore, this failure is also caused by lower rate of students' habits of mind. Habits of mind are a set of skills that enable students to think and find solutions of problem easily[10].

Habits of mind involve two major characteristics, namely 'thinking' and 'habituation'. The thinking dimension represents the ways of thinking, whereas habituation dimension means attitudes or behavior ways of thinking[11]. In a mathematical context, Cuaco explained that habits of mind in mathematics (mathematical habits of mind) is a thinking habituation done by students in facing the mathematical problem. These habits involve habits of looking for pattern, experiment, explaining, finding, visualizing, composing conjecture, and guessing[12].

II. METHODS

The method adopted in this study was qualitative research approach. More specifically, it was a case study conducted at a senior high school in Medan, North Sumatera. The subjects were students in grade XI at the school. The instrument used were tests, including indicator of mathematical critical thinking and mathematical habits of mind, observation, and interview. The data were analyzed using descriptive analysis method to look into students' decision-making style in mathematical habits of mind.

The indicator and rubric of mathematical critical thinking used in this study were adopted and then modified according to Ennis and Hendriana et al[12]-[13].

1. Investigate the truth of arguments, statements and process solutions
2. Identify the relevant and irrelevant data of mathematical problems
3. Analysis and inference the mathematical problems

The students' mathematical critical thinking was analyzed by using the four core steps in critical thinking process.

Table 1:Rubric Score of Mathematical Critical Thinking Skill.

Indicators	Explanation	Score
Interpretation	Identifying mathematical process/concept on a situation given, asked, and checking the sufficient data.	0 – 3
Analysis	Analyzing and explaining the question, answer and argument.	0 – 3
Evaluation	Deduce and analyzing deduction.	0 – 3
Inference	Formulate the explanation, hypothesis and conclusion.	0 – 3

The way of the calculation of percentage values is as follows:

$$\boldsymbol{Percertage = \frac{Score\ obtained}{Maximal\ Score} x100\%}$$

The result of students' answer sheet was analyzed based on the rubric score of mathematical critical thinking skill and then it was categorized based on the table below [14].

Table 2: Category of Percentage of Mathematical Critical Thinking Skill.

Interpretation (%)	Category
$81{,}25 < X \leq 100$	Very high
$71.5 < X \leq 81{,}25$	High
$62{,}5 < X \leq 71.5$	Moderate
$43{,}75 < X \leq 62{,}5$	Low
$0 < X \leq 43{,}75$	Very low

Next, the students' answer sheet was analyzed based on the types of decision making style. The kinds of the decision-making style are as follows[5]-[8]:

Table 3: Types of Decision-making style.

Types	Explanation
Analytic	Over-analyze. It means that more accurate and more detail, well structured.
Directive	Structured. It means that data presented based on facts and its form is structured.
Conceptual	Its characteristics are creative and broad outlook.
Behavioral	It tends to give an opinion and unstructured.

Finally, the results of mathematical critical thinking test were analyzed based on the mathematical habits of mind test. This research used the indicators of mathematical habits of mind by Costa and modified by Hendriana et.al, namely persisting, managing impulsive, listening other people opinions with understanding and empathy, thinking flexibility, thinking metacognitive, striving and accuracy, asking and posing the question effectively, applying the past knowledge to the new knowledge, thinking and communicating with clarity and precision, gathering data through all sense, creating, imagining, innovating, responding with wonderment and awe, taking responsible risks, humorous, thinking

interdependently, and continuing learning[12]. The score of mathematical habits of mind were obtained and analyzed by using *Linkert* scale.Thus, the criteria of the score of students' mathematical habits of mind used were as follows:

Table 4. Category of Mathematical Habits of Mind

Score	Category
$X > 133$	Very high
$110 < X \leq 133$	High
$86 < X \leq 110$	Moderate
$63 < X \leq 86$	Low
$X \leq 63$	Very low

III. RESULTS AND DISCUSSION

3.1 Results

The research was conducted in class XI at one of senior high schools in Medan. The material was the derivative application with mathematical critical thinking indicators. The results of the scoring of critical thinking skill showed that more than half of students' mathematical critical thinking skill are still low, so they have the behavioral style of decision-making. In addition, most of the students get lower scores of mathematical habits of mind. The further explanation is presented in the following table.

Table 5: Score of Mathematical Critical Thinking Skill, Decision-Making Style, and Mathematical habits of Mind.

Student	Mathematical Critical Thinking Skill	Decision-Making Style	Mathematical Habits of Mind
1	47%	Behavioral	86
2	53%	Behavioral	97
3	89%	Analytic	137
4	100%	Analytic	140
5	78%	Directive	117
6	78%	Directive	129
7	67%	Directive	126
8	50%	Behavioral	98
9	39%	Behavioral	96
10	39%	Behavioral	108
11	33%	Behavioral	78
12	53%	Behavioral	70
13	50%	Behavioral	87
14	22%	Behavioral	80
15	33%	Behavioral	83

From the tabel shown that most students have the behavioral style of decision-making. In addition, most of them get the lower score of students' mathematical habits of mind.

3.2 Discussion

From table 4, we can see that there are 2 students are analytic style and 3 students are directive style. In contrast, there are 10 students are behavioral style. For the category of mathematical critical thinking skill, it was found that 2 students are very high, 2 students are high, 1 student is moderate, 5 students are low, and the rest of them are very low, so it can be said that most of them are still low in mathematical critical thinking skill. Furthermore, it was shown the problem given below:

For problem 1, the indicator is analysis and inference of the mathematical problems. See the following function. For instance, students were asked to determine2015^{th} derivative of the function $f(x) = (x+1)^{2015} + (2x-1)^{2014}$.

Figure 1 shows that one of students has the analytic style. It is evident from his ability to solve a problem more accurately, in a well-structured manner and providing more detail. The student knows why the derivative$(2x+1)^{2014}$ resulting 0 in the 2015th derrivative. The student with this style could answer more detail by explaining the concept of this problem and they understand the problem better than others, as shown in the figure below:

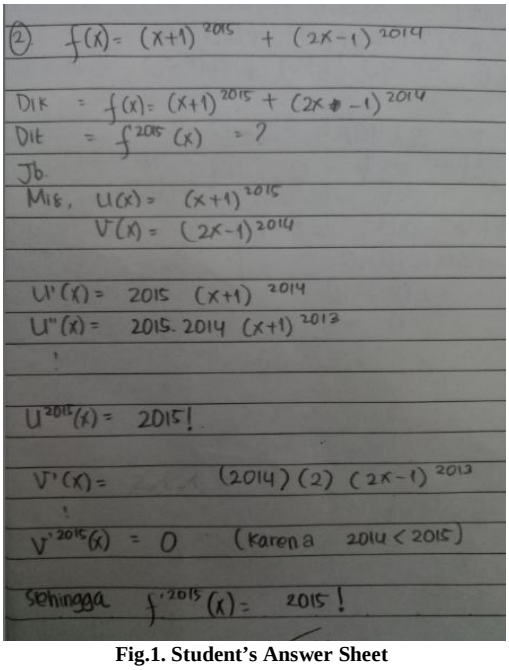

Fig.1. Student's Answer Sheet

Figure 2 displays the student's directive style. They can analyze the data based on the fact givenbut their results were incorrect because their calculation has not finished. Their calculation has not finished because they just knew and remember the properties of derivative without understanding. Moreover, they could solve the routine problem, so when they were

given more complex problems, they had difficulty to solve them.

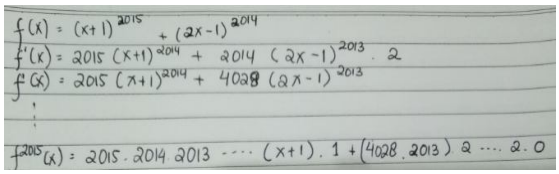

Fig.2. Student's Answer Sheet

Figure 3 represents that most of the students have the behavioral style, because they could not understand the problem. They were confused to identify, analyze, deduce, and moreover formulate the final decision. They have not comprehended the concepts and properties of derivative, so they were not able to solve the complex problem. In solving the problem, they just used their assumption and opinions without the derivative concept.

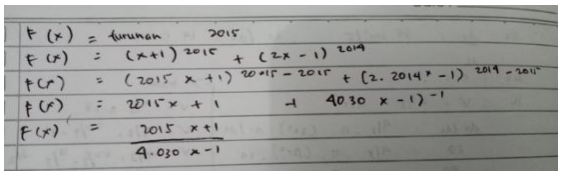

Fig.3. Student's Answer Sheet

For number 2, the indicator is investigating the truth of arguments, statements and process of solutions. For instance, Check the truth of the statement below: "If given two real positive numbers those are *a* and *b* with $\sqrt{a}-\sqrt{b}=20$, so the maximum value $a - 5b$ is 500."

The results showed that most of them answered incorrectly. Only five students were able to solve the problem about how to determine the value of maximum and minimum function. Figure 4 presents that one student understood the derivative application concept about maximum value. The student not only used the first derivative to find out the maximum value, but they also comprehend how to apply the concept of turning point function in derivative application. As a result, they fulfilled the four steps in the critical thinking process, so they have the analytic style.

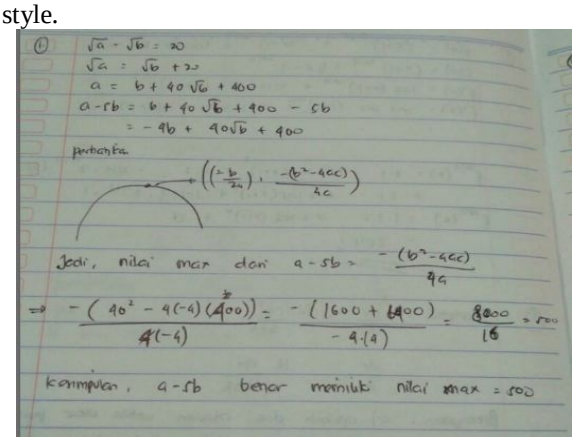

Fig.4. Student's Answer Sheet

Figure 5 shows that the students have derivative style. They could answer correctly and structured, but they did not understand well the maximum value in derivative application concept. They were focused to find out the value of *a* and*b*, so they did not apply the derivative concept to solve this problem. They just used the concept of quadratic function. Also, from the interview session, they said that they were rushing in answering the problem.

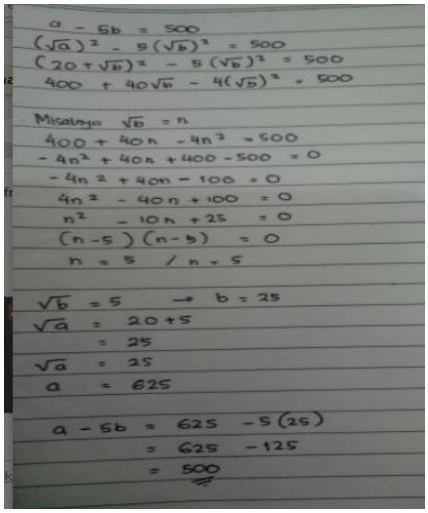

Fig.5. Student's Answer Sheet

Figure 6 represented that the students just used their opinion and assumption to solve this problem. They could do the interpretation and analyze the problem well. The students input the value of *b* with $40/8$, they did not write in their answer sheet how to get it. In the interview session, they explained that they were still confused to apply the derivative concept in this problem. They just chose arbitrarily the value of *b* and then did the calculation. Hence, these students were categorized as the behavioral style.

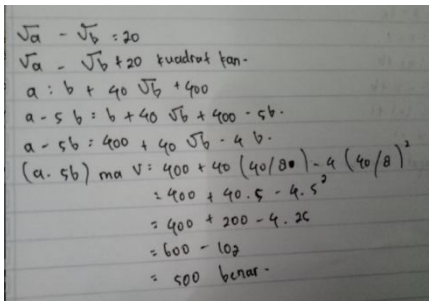

Fig.6. Student's Answer Sheet

The problem number 3 consist of the indicator of identifying the relevant and irrelevant data of mathematical problems. For instance, "Given a balloon-shaped balloon. The balloon is inflated with an air acceleration rate of 88 cm^2/s and the rate of increase of the balloon radius of 14 cm/s. Are the available data relevant to measure the volume

increase after the ball is blown? If yes, how to solve it? If not, what is the reason?".

Figure 7 shows that the students could answer in a more accurate, detailed, and more technical manner. They can apply the concept of derivative in velocity. They could interpret and analyze the problem well. Consequently, they could do the right strategy to solve the problem and choose the correct final conclusion.

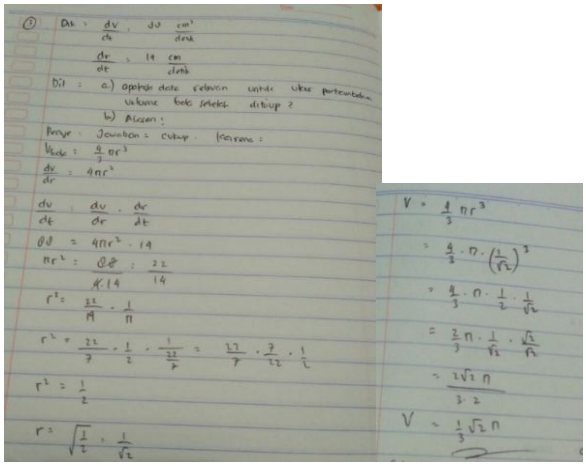

Fig.7. Student's Answer Sheet

Figure 8 shows that the student understood the problem because they could do the interpretation phase and analysis phase. For evaluation phase, they did the wrong calculation for finding the value of *r*. They had difficulty in finding the derivative of the root equation. They did not fully have concentration in solving the problem. Hence, their style of decision making is derivative.

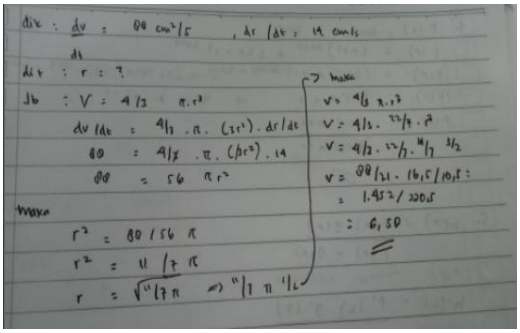

Fig.8. Student's Answer Sheet

Figure 9 shows that the students could not answer correctly because they did not understand the problem. They could not identify the problem well. As a result they were not able to evaluate and inference correctly. They just determined the problem based on their opinion. From the interview found that they did not have the curiosity in solving problem so they were quick to conclude this problem could not be solved. Accordingly, they are categorized as the behavioral style.

One of the reasons the students could not understand the derivative topic is because the teacher often gave them the routine question and seldom to gave the challenging question about derivative so their critical thinking skill did not develop. In learning activity, in is found that teachers still used the direct instruction method without encouraging and motivating students to be active. This situation caused the low level of students' mathematical habits of mind (see Table 4).

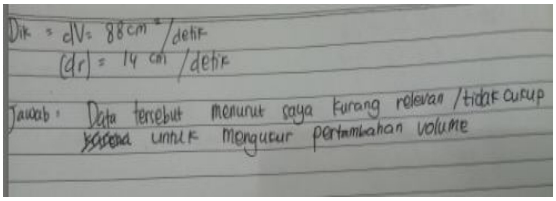

Fig.9. Student's Answer Sheet

These results were supported by interview and test about the mathematical habits of mind based on the test questionnaire including 39 questions of mathematical habits of mind. The lower score in the indicator of persisting, thinking flexibility, thinking metacognitive, striving and accuracy represented that the mathematical habits of mind of students are still low. Most of them were prefer to give up in solving the difficult problem. They assumed that math is difficult because they need an extra capability to face problems. It was similar to the observation during the test. Before they tried to solve it, they directly complained to the problem given. They were not confident with their ability to solve the problem. They had no targets for mathematical achievement so they worked with caution in resolving the given questions.

CONCLUSIONS AND SUGGESTION

To conclude, more than half of the students possess critical thinking skill that is still on the lower cognitive complexity based on the decision-making stylein derivative topic. More than half of them have the behavioral style of decision-making. These happened bacause the students'mathematical habits of mind are low. The suggestion for future research is to find the appropriate innovative instructional method to enhance the students' mathematical thinking skill and mathematical habits of mind so the students' decision making can change for the better.

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