Analyzing the effect of students’ habits of mind to mathematical critical thinking skill

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Abstract. Critical thinking is an essential skill to enhance students’ capability in Mathematics. One of the factors that can affect this skill is Habits of Mind, because the implementation of Habits of Mind in mathematics learning can help the ability to think logically, systematically, accurately, and even critically. This research aims to analyze the effect of students’ Habits of Mind to mathematical critical thinking skill. The sample of this study were 30 students of senior high school from 11th grade (aged 15 – 16 years) in one of the public schools in Medan, North Sumatra, Indonesia selected by using purposive sampling technique. As a quantitative research, this research uses a linear regression statistic. The data is collected through a series of test, observation and interview. The results show that the students’ Habits of Mind affect the students’ mathematical critical thinking skill significantly, in which Habits of Mind has the effect of contribution as much 51.4% to mathematical critical thinking skill. It describes that Habits of Mind give a positive effect to the mathematical critical thinking skill. It is obtained by applying the regression linear test toward the students’ score in mathematical critical thinking skill and Habits of Mind.

1. Introduction
One of the aims of education in Indonesia according to the Law number 20 of 2003 [1] and the Organisation for Economic Co-operation and Development (OECD) Learning Framework 2030 [2] is developing students’ potential. By following any means of education, students will be prepared to be able to not only face, but also handle a real life problem in the future. In other words, it can be said that education is the fundamental starting ground that constructs factors in developing quality good human resources [3]. A good human resources is a highly-qualified people who either is able to meet the labor market demands or has the ability to think critically [4]. Critical thinking ability is one of the most important abilities to be developed in education based on the 21st century skills [5] [6], in which according to Lamb, Maire, Doecke [6], these skills describe and combine the broad range of skills that students would need to master in order to succeed in today’s life. Therefore, critical thinking allows someone to create breakthrough, verify facts and think outside the box [7].

Ennis [8] described critical thinking skill as a skill which is to aid someone effectively to decide what decisions must be believed and done. Glaser [9], Primack [10], and Wilson [11] stated similarly that critical thinking skill can affect students’ potential directly by applying series of informations effectively so they can decide the best alternative solutions in solving a problem. Critical thinking is seen as one of important goals in Indonesian education, because it helps developing
students’ ability to think critically. In order to be able to realize this goal, the government has carried out educational programs by offering various disciplines to students, one of them is Mathematics. Mathematics is called the queen of science, because it is the basic understanding to connect to other disciplines [12]. In addition, mathematical problem can shape students’ way of thinking in a process of understanding how the world works [13], because Mathematics is formed based on the result of thinking related to thinking an idea, processing, and reasoning[14]. Thus, Mathematics can aid students’ critical thinking development in order to be logic and rational[15].

Critical thinking skill is an important skill to be developed in mathematical learning. Unfortunately, the students’ mathematical critical thinking skill is a little shallow for junior and senior high school students [16][17]. One of the reason that causes the lack of students’ mathematical critical thinking is the low of students’ Habits of Mind[18]. Habits of Mind is one of the principal component [19] and intellectual resources that necessary in critical thinking skill [20]. Loyd [21] explained that the learning method in implementing the Habits of Mind strategy can give students opportunities to have habits, such as: perseverance, metacognition, a sense of humor and think flexibly in solving problems. In the previous researches, researchers found out that Habits of Mind alters students critical thinking[22] especially in Mathematics [23]. Dwirahayu, Kustiawati, and Bidari [24] characterized the impact of Habits of Mind as the contributing factor toward mathematical ability. Alhamlan et al., [22] added that the Habits of Mind can also develop a mathematical critical thinking skill. According to Miliyawati [25], the Habits of Mind is an important application in the mathematical learning process, because the mathematical learning process that implement Habits of Mind can improve students’ mathematical critical thinking skills. Umar [26] showed the result that the instructional model that uses Habits of Mind is better than the instructional model without the Habits of Mind. These researches revealed that mostly the discussion about Habits of Mind and critical thinking skills in Mathematics aroused around the correlation between Habits of Mind and mathematical studies. Unfortunately, the question about how deep is the contribution of the Habit of Minds to students’ critical thinking skills in Mathematics has not yet to be explored. This paper aims to describe the relation of Habits of Minds to mathematical critical thinking skills and how much Habits of Mind contributes to mathematical critical thinking skills.

1.1 Mathematical Critical Thinking (MCT) skill

Critical thinking, is a mental activity that involves: identification (knowing and understanding), examination and verification as well as result evaluation[27]. Beyer [28] defined critical thinking as a thinking process that is used by someone to evaluate and validate any kind of information he/she received. In addition, American Philosophical Association (APA) stated that critical thinking as a skill to analyze, interpret, explain, evaluate, observe and examine over own thought [29]. An individual is called a critical thinker if they are able to ask critical questions and untie crucial problems. A critical thinker has the capability to solve a crucial problem by; gathering and assessing a relevant information and also concluding a reasonable solution. A critical thinker would also have the traits to be open minded in identifying and assessing assumptions, implications and they also will always be aware of the consequences by always communicating with others[30]. As a result, mathematical critical thinking (MCT) can be concluded as the process of using thinking skills effectively by students to compile, evaluate and apply the best decision in mathematical problem[8, 9, 10, 11, 27, 28, 29].

1.2 Habits of Mind (HoM)

Habits of Mind (HoM) is an affective aspect relating to how an individual interprets problem solving such as; confidence, perseverance, accuracy, and flexibility in finding alternate strategies to solve problems. Fundamentally, Habits of Mind consist of two dimensions such as; thinking (describing the way of thinking) and performing habits (reflecting the attitude and behavior of the way of thinking) [31]. In mathematical context, the term of “Habits of Mind” is interpreted as the students’ intellectual behavior in facing mathematical problems, like creating, finding, guessing, and experimenting [32].

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In one hand, Jacobbe and Millman [33] said that Habits of Mind in mathematical context consists of some characteristics such as; (1) exploring mathematical ideas; (2) formulating questions; (3) giving examples; (4) identifying strategy of problem solving which is useful in the broad scale; (5) asking themselves whether there is “something more” and the mathematical activity that has been done (a generalization); (6) reflecting their answer to look for whether there is an error or no.

In the other hand, Costa and Kallick [21] proposed sixteen characteristics of Habits of Mind such as; persisting, managing impulsive, listening other people opinions with understanding and empathy, thinking flexibility, thinking metacognitively, 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 to learn. Based on the above explained characteristics of Habits of Mind by Jacobbe & Millman[33] and Costa & Kallick [21], this article uses the sixteen characteristics of Habits of Mind by Costa & Kallick [21] because these indicators have the complete set of indicators of Habits of Mind according to Jacobbe and Millman[33].

2. Method
This article used quantitative method to investigate the effect of the students’ HoM to their MCT skill. The 30 students from 11th grade (15 – 16 years old) were selected from one of a senior high school in Medan, North Sumatera by using purposive sampling technique. They were chosen because they are students in IPA class (science major). The instrument used were tests, including indicators of MCT and mathematical HoM, observation, and interview (unstructured format). The unstructured format was chosen to verify and explore students’ answers on tests of MCT and HoM do not require interview guidelines to be arranged systematically and completely [34]. First, we designed five tasks included indicator of MCT adopted from Fisher [35] and Hendriana et al [36] to assess students’ MCT skill. Second, there were 28 questions on the questionnaires of HoM adopted from Costa and Kallick[21], in which these instruments were designed to assess the students’ HoM (see some questions in Appendixes 1). Before doing the test, both instruments were given to students that is out of the sample to test its validity and reliability. During the test, students were given 100 minutes to solve the MCT tasks and 45 minutes for answering the mathematical HoM questionnaire. Next, during the interview session which around 60 – 75 minutes, students were asked to explain their ideas in solving the problems, as well as to clarify their answer in the questionnaire of HoM. Meanwhile for the observation session, the learning and teaching observed was used as an additional information to support the findings in this study.

The quantitative data was used to investigate the effect of HoM to MCT skill, by using a linear regression statistical methods with the help of SPSS (Statistical Package for the Social Sciences) software. In addition, a descriptive analysis on interview and observation during the lesson in the class was also carried out.

3. Results and Discussion
The result of the regression test between the score of students’ MCT test using by 5 questions consisting of 5 indicators of MCT adopted from Fisher [35] and Hendriana et al [36], which are:

**Question 1**: Investigate the truth of arguments, statements and process solutions
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.”

**Question 2**: Identify the relevant and irrelevant data of mathematical problems
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?
Question 3: Analysis and inference the mathematical problems
Determine $2015^{\text{th}}$ derivative of the function $f(x) = (x + 1)^{2015} + (2x - 1)^{2014}$.

Question 4: Identify the sufficient data of mathematical problems
Suppose that $h(x) = \frac{f(x)g(x)}{f(x) - g(x)}$ with $f(2) = 3$, $f'(2) = 6$, $g(2) = 1$, dan $g'(x) = 4$. Is these informations sufficient to determine the value of $h(2)$? Explain!

Question 5: Solve mathematical problems accompanied by relevant reasons.
Known that the tangent of parabola $y$ forms an angle to the $x$ axis of $\arctan(6)$. Determine the equation of the tangent through point $(2.1)$!

and the scores of students’ HoM measured by using a questionaiere containing 39 questions (see some questions in Appendixes 1) shows:

3.1 Linearity Test

| Model   | Sum of Squares | Df | Mean Square | F        | Sig. |
|---------|----------------|----|-------------|----------|------|
| Regression | 502.954        | 1  | 502.954     | 31.631   | .000 |
| Residual | 445.212        | 28 | 15.900      |          |      |
| Total    | 948.167        | 29 |             |          |      |

a. Dependent Variable: MCT
b. Predictors: (Constant), HoM

Table 1 shows that the model of regression fulfills linearity criteria, in which Sig (0.000) < 0.05. In the other words, the model of regression equation is significant, it means that the MCT regression equation for HoM is linear. It means that the predictor variable (HoM) in the regression have a straight-line relationship with the outcome variable (MCT). The linearity test is one of assumption test of linear regression test. Since the the MCT regression equation for HoM is linear, then the test is continued to analyze the linear regression test.

3.2 The Linear Regression Equation and The Significance of Correlation Test

Based on Table 2, the equation of linear regression is $\hat{Y} = -33.135 + 0.370X$. In addition, the result of analysis shows that the Sig.(0.00) < 0.05, it means $H_0$ is rejected. Hence, there is an effect of the students’ HoM to the students’ MCT significantly. Furthermore, the results of analysis (Table 3) shows that the correlation of HoM and MCT is strong, in which $r_{xy}$ is 0.728. In addition, HoM has the effect of contribution as much 51.4% to MCT, and 48.6% others affected by factors is out of HoM, based on the value of R square (coefficient of determination). It is shown that HoM can give more effect to MCT than other factors, such as self concept [37].

Table 2. Coefficients

| Model   | Unstandardized Coefficients | Standardized Coefficients | t    | Sig. |
|---------|-----------------------------|---------------------------|------|------|
|         | B                           | Std.Error                 | Beta |      |
| (Constant) | -33.135                    | 7.911                     | -4.189 | .000 |
| 1 HoM    | 0.370                       | 0.066                     | 0.728 | 5.624 | .000 |

4
a. Dependent Variable: MCT

Table 3. Model Summary

| Model | R       | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|---------------------------|
| 1     | .728*   | .530     | .514              | 3.988                     |

a. Predictors: (Constant), HoM
b. Dependent Variable: MCT

From Table 2 and Table 3, the result is explicitly clear that the students’ HoM can give positive effect to the students’ critical thinking [19, 18]. From the intellectual behavior of HoM [21], the indicator of persisting, thinking flexibly, thinking metacognitively, striving and accuracy give more effects to MCT skill [17], because the kinds of HoM which are necessary for being a critical thinker are having a open-mindedness, a desire for verifying the truth, an inquiring attitude, and a respect for the final results of a problem [20].

These findings are supported by the results of interview and observation that most of the students who are having lower score in critical thinking were feeling unconfident about themselves [38]. The students who did not have enough confidence in themselves were easily give up when they were faced a difficult problem without trying to analyze the problems. This condition is due to the lack of eagerness to solve the problem. The observed behavior, such as; feeling anxious when working on given test, showed that those students had bad habits, like a tendency to look for the quick answer and a lack of determination when the answer is not obvious. They assumed that those problems were difficult [39]. Moreover, during the MCT test using 5 questions consisting of 5 indicators of MCT adopted from Fisher [35] and Hendriana et al [36], students felt anxious and tried to look for help from their friends. These were conditions illustrated that the students did not use the best of the remaining time to solve the problem. They did not dare to take the risks and responsibilities in decision making process which made them difficult to survive in difficult situations. These habits was shown from their behavior when doing the test, they preferred to ask their friends about the correct answer than to do it by themselves. Consequently, it causes the students’ MCT skills to be low, because the low level of HoM ability can have a detrimental effect on student achievement [40]. This finding was supported by Miliyawati [25] that if bad habits are done continuously, then it can shape a bad behavior for everyone, like the way of thinking.

Furthermore, the low of HoM is caused by the inappropriate learning [41]. The observation result showed that the learning activity was more focused to teacher-centered approach which students were being the object of the learning process. The learning process that is teacher-centered can cause students to be passive and to giveless meaningful contributions in learning activities [42]. Similarly, the result showed some students who were passive during the lesson received lower score in MCT than the active students. One of reason that make students are passive is because the Mathematics subject was not taught well enough in order to attract those students’ attention or Mathematics was taught in a dull way of teaching so make students felt uninterested and quickly assumed it was difficult [43]. As a result, they were not curious and interested. If the students were able to feel easy while learning Mathematics, they would learn well. On the contrary, if they already think about Mathematics in a dull way, so they will not learn good enough. So, based on the previous explanation, HoM can affect students’ skill, such as students’ MCT skill.

On the other hand, the condition of students who did good in the MCT test would show the flexibility which they consider other point of views in evaluating opinions [21]. The flexibility here is to be creative, in which students are flexible to generate many ideas so that they were able to solve the
problems effectively. Those students were more confident, responsible and dare to take risks in problem solving. These kind of behaviors represent the HoM and attitudes of MCT so that those two variables (MCT and HoM) are intertwined. To sum up, it can say that HoM can give impact to MCT, in which if the HoM is good, so the MCT will be good also, and vice versa.

4. Conclusion and Suggestion
This paper concludes that the Habits of Mind presents a positive effect to the mathematical critical thinking skill by applying the regression linear test toward the students’ score in mathematical critical thinking skill and habits of mind. The result shows that the students’ Habits of Mind contributes more, approximately 50%, to students’ mathematical critical thinking skill. Thus, eventually the students’ Habits of Mind affects students’ mathematical critical thinking skill.

However, this research has not yet discussed in more details regarding another factor that potentially affects the mathematical critical thinking skill, one of them such as; self concept. For the further research, we wonder whether those factors (one of them such as; self concept) can also affect students’ mathematical critical thinking skill. Thus, the result is expected to aid teachers to design more appropriate model to enhance students’ mathematical critical thinking skills through those factors.

Appendixes 1: Questionnaire of HoM

| Questions                                                                 | Responses |
|--------------------------------------------------------------------------|-----------|
| I remain passionate in solving problem the difficult ones                |           |
| I avoid working on the complicated questions                             |           |
| I refuse to agree with the others opinions even though there is additional relevant mathematical information |           |
| I ask myself whether my answer is correct                                |           |
| I think of the appropriate steps to get a solution to a mathematical problem |           |
| I shy away from thinking about the targets achieved after studying derivative topics |           |
| I re-studied topics that I did not understand                            |           |
| I am unconcerned whether my answer is correct or no                      |           |
| I re-checked the answers of assignments I had already done              |           |
| I disregard the use of formulas/rules used in solving mathematical problems |           |

Note: SS : Strongly agree; S: Agree; TS: Disagree; STS: Strongly disagree

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