Students’ critical thinking skills in modeling based learning

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Abstract. This research aims to describe students’ critical thinking skill in trigonometric ratios through modeling-based learning. A sample of 30 tenth grade students in MAN 3 Palembang was chosen as research subjects. The learning process is customized to follow the principles and characteristics of modeling based learning. Data were collected using 3 essay test and analyzed using a descriptive method. The results show that less than ten percent of the subjects have poor critical thinking skill.

1. Introduction
Mathematics is one of the compulsory subjects which provides students with a critical thinking skill. According to Indonesian Curriculum 2013 [1], the aim of mathematics learning is to prepare the students to face the changing situations in life and the advancement of the world, by educating them to act based on their critical, creative, innovative, and mathematical thinking and apply it in a real life. Mathematics is needed to face the challenges of a changing world in the 21st century [2,3]. One of these skills is critical thinking and it can be gained from learning mathematics [3].

Critical thinking is becoming an urgency on the facing the world challenges in the 21st century. According to [4], critical thinking prepares students to be successful citizens because they are able to make decisions and solve modern life problem with ingenious ways. The benefit of critical thinking in the long term can support the students to manage their skill and empower the individual to contribute creatively to the profession they select [5]. By thinking critically, the students could reflect the problems deeper, keep the minds open, analyze the problem and think reflectively and evaluatively [6]. Therefore, critical thinking is an important skill for students to be improved.

The critical thinking skill can be seen from the mathematics results of Indonesian students who were participating in PISA. Indonesia ranked the second lowest in 2012 and the ninth lowest in 2015 [7,8]. The analysis of PISA results found that students in Indonesia are having difficulties in relating the mathematical concept and the real-life contexts. The students in Indonesia are only able to master a routine issue, simple computing, and solve the daily contexts problem. As mention in [9], most students in Indonesia were not familiar with PISA problems and the teacher usually presented in the classroom or available in the textbooks and student worksheet are of level one or level two. Students tend to learn only by memorizing the formulas. This does not lead the students to the thinking activity of learning mathematics. However, this gives a bad impact on the students’ mental development and causes the students to lose the sense of learning because of getting used to imitate the teachers and not accustomed to thinking critically.
One of the efforts which can be done to solve the problem is by implementing the active learning. According to [10], mathematical modeling can be taught. The learning process with mathematical modeling named as Modeling Based Learning. By applying the modeling based learning, students will study more meaningfully and actively. Besides, modeling can bridge the life experience and mathematics. In line with [11] who states modeling may encourage the students to a deeper understanding and train them to reflect, interpret and formulate a solution for unusual problems. Modeling is also known as one of the aim of mathematics learning in school according to [1] and successfully submitted to the curriculum in some countries such as Singapore [12] and Australia [13]. The researchers are interested in students critical thinking skills in modeling based learning.

2. Methods
This research is a descriptive research. The aim of this research is to describe students critical thinking skill after applying a modeling based learning to X\textsuperscript{th} graders of MAN 3 Palembang. The subject of this research was about 30 students in class X MIA 4 of MAN 3 Palembang and was conducted in academic year 2017/2018.

The procedure of this research consists of 3 stages, which are preparation, implementation, and reporting. In the preparation stage, the researchers devised a Trigonometric lesson plan with modeling based learning, Modeling students worksheet, and a critical thinking skill test. In the implementation stage, researchers conducted 2 meetings for the learning processes and 1 meeting for the critical thinking test. While the reporting stage is done by converting the score into test value and make the results of it.

The implementation of modeling based learning in this research followed steps developed by COMAP and SIAM [14]:
1. Identify and specify the problem to be solved,
2. Make assumptions and define essential variables,
3. Use mathematics to get a solution (mathematizing),
4. Analyze and asses the model and solution,
5. Iterate as needed to refine and extend the model,
6. Implement the model and report results.

Figure 1. Mathematical modeling process
2.1. Data Collection

After applying the modeling based learning, the students were given the critical thinking skill test. The questions of the test are trigonometric questions based on the indicators of critical thinking skill. There are 3 essay tests which aim to find out the critical thinking skill in trigonometric ratio. The questions were scoring by the researchers according to the test scoring guidelines as shown in table 1 below.

| Indicator       | Desciptor          | Score |
|-----------------|--------------------|-------|
| Interpretation  | Interprete appropriate | 3     |
|                 | Interprete inappropriately | 2     |
|                 | Interprete but wrong  | 1     |
|                 | Did not Interprete   | 0     |
| Analysis        | Analize appropriate  | 3     |
|                 | Analize inappropriately | 2     |
|                 | Analize but wrong    | 1     |
|                 | Did not Analize      | 0     |
| Inference       | Infer appropriately  | 3     |
|                 | Infer inappropriately | 2     |
|                 | Infer but wrong      | 1     |
|                 | Did not Infer        | 0     |
| Evaluate        | Evaluate appropriately | 3     |
|                 | Evaluate inappropriately | 2     |
|                 | Evaluate but wrong   | 1     |
|                 | Did not Evaluate     | 0     |

3. Results and Discussion

The results of this research were based on the student’s answer sheets which were given on Thursday, April 5th, 2018. The test results are scored and converted into value to be categorized. The frequency distribution data can be seen in the table below.

| Value of the Test | Category | Critical Thinking Skill |
|-------------------|----------|-------------------------|
| 90 - 100          | Excellent| 4                       |
| 70 - 89           | Good     | 15                      |
| 50 - 69           | Average  | 8                       |
| 41 - 49           | Poor     | 3                       |
| 0 - 40            | Very poor| 0                       |
|                   | Average Value | Good  | 73.70          |

According to Table 2, the critical thinking skill of the students in the X MIA 4 of MAN 3 Palembang is divided into 5 categories; i.e., excellent, good, average, poor and very poor category, but there is no student who has a very poor value. Based on the data above, there are 13% or about 4 students in the excellent category, 15% or about 15 students in the good category, 26.7% or about 8 students with the
average category, and 10% or about 3 students in the poor category. The Average value in that class is 73.70 or in the good category.

Then, the test results are categorized base on each indicator of critical thinking skill. The data are shown in Table 3 below.

Table 3. The category on the average value in the class indicator of critical thinking

| Indicator | Average Value of The Class | Category |
|-----------|----------------------------|----------|
| Interpretation | 96.67                      | Excellent|
| Analysis   | 75.83                      | Good     |
| Inference  | 41.11                      | Poor     |
| Evaluate   | 90.56                      | Excellent|

In Table 3, we can see that each indicator of critical thinking skill has different categories. The highest average value is in the indicators of interpretation which has an excellent category. The lowest average value is in the indicator of inference which has the poor category. There is a big difference between the average value of the interpretation and inference. The average value of the inference is just a half of the interpretation. In other hands, the indicator of interpretation and evaluating have a close value with a small difference but still in the same category (Excellent).

The test results of critical thinking skill are in a good category because of the implementation of modeling based learning. If we looked back to the students’ worksheets, the students who were concentrating while following the learning process and pay attention to the worksheets, have a good score in the test. Besides, because of the characteristic of modeling based learning is to create students active learning and students centered learning, these students may have different strategies for answering the question in the worksheet. This behavior affects the test results of critical thinking itself. It can be seen from how the students answer the first question in many points of views. This habit developed while the students were studying using modeling based learning and being accustomed to think more critically.

The indicator of interpretation was the highest average value rather than the other indicators. This was affected by the activity of identifying the problem which is improved in the first meeting. In the “identify the problem” stage, students learned to understand the problem and interpreted them to a picture. It was in line with the indicator of interpretation that students must understand the problem by illustrating the problem to a picture. Students were very accustomed to this and most of the groups who were able to identify the problem clearly in a picture caused the average value of the class in interpretation indicator excellent (96.67).

The analysis is one of the indicators which is valued the most. The average value of this indicator was affected by the assumption in the modeling based learning process. The assumption stage was started from the informal to the more formal learning process. This stage is the most difficult stage for many students. It's comparable with the critical thinking test results. Some of the students who are able to assume correctly and explain it clearly and in detail got the highest score in the indicator of analysis. In spite of it, the indicator of analysis does not have the lowest average value.
The answer to the question number 2b from the student with very good category

Figure 2 and figure 3 showed clear differences between students in the very good category and the students in the others categories. The indicator of analysis not only measured by one question, but also the answers of number 2b described the critical thinking skill of the students well. A very good analysis indicated the level of students critical thinking itself and led them into a good way of inference the problem solution.

The inference is the indicator of critical thinking skill which has the lowest average value with the poor category. The inference was instilled in the “implementing the model” stage while learning with modeling. Most of the students passed the learning process very well, but the fact does not show accordingly. After taking a closer look at the test results, the students who didn’t inference well because they didn’t analyze well. Although they had analyzed the problem well, they are having difficulty inferring the results to correlate with the problem. This fact is one of the lack of this research which the researcher didn’t presume that correlation.

The indicator of evaluating is the indicator of critical thinking skill with the excellent category. This indicator was affected by “iterate and extend model” stage in modeling based learning. In the critical thinking skill test, the questions trigger the students to use the mathematical formulas in order to solve the problems as in the iteration stage. After the students discover the right model, they would apply it to the problem and checked whether the formula works in all cases or not. Most of the students iterated
correctly in the learning process, therefore it’s very reasonable if the average value of the class in the indicator of evaluation is Excellent.

The average value of critical thinking skill test was 73.70 with a good category. This value tends to the analysis value which has the same category. Indirectly, the indicator which affected so much is analysis because it can be shown from the students’ test results which depend on their analysis skill. Moreover, the analysis skill affects the inference skill. If the students analyzed the problems incorrectly, mostly they would have difficulties to infer.

4. Conclusion
Based on the results of the research in the X grade students of MIA 4 of MAN 3 Palembang, it can be concluded that the modeling based learning encouraged students’ critical thinking skill which categorized as good with details: 4 students are excellent, 15 students are good, 8 students are average, 3 students are poor, and no students with very poor category. The highest average value in indicator of critical thinking is the interpretation which is 96.67 with the excellent category. Meanwhile, the lowest one is inference which is 41.11 with the poor category.

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