Improving mathematical critical thinking skills through problem-based learning

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Abstract. This research was conducted to improve students' mathematical critical thinking skills by using problem-based learning models. The type of this research is quantitative which is designed as an experimental model, using the nonequivalent control-group pattern. Sampling is not done randomly. A sample of 76 people consisted of two classes. Both classes are given different treatments. Retrieval of data, carried out tests twice, namely Pre-test and Post-test. Data were analyzed using an independent sample t-test. Hypothesis test results, there is an increase in mathematical critical thinking skills, where the t-test at a value (sig. (2-tailed)) is less than the value of α. In conclusion, problem-based learning can improve mathematical critical thinking skills. Keywords: Mathematical critical thinking ability, problem-based learning.

1. Introduction

Education is a deliberate and planned effort to create a learning atmosphere, the learning process in the classroom is expected to enable students to actively develop their potential to obtain religious spiritual strength, self-control, personality, intelligence, noble character, and skills needed by themselves and society. Education in principle is to develop the teaching of special skills, and also something that cannot be seen but more deeply that is giving knowledge, consideration, and wisdom.

Learning in the classroom of teachers is emphasized to always pay attention to learning models, using the learning model of the teacher and students can be helped to conduct learning interactions. The purpose of using a learning model is to make it easier for the teacher to explain the material or teaching material not to spawn. Using the learning model makes it easier for students, to quickly understand the material presented by the teacher when explaining in class. For example, learning by applying a learning model, the teacher prepares various kinds of problems that are related to the topic or subject matter taught at that time, students are asked to be able to solve correctly and on time the problems that the teacher sets.

Improving students' thinking skills is the main focus of educators, especially in mathematics teachers. Learning mathematics is closely related to the activities and processes of learning and thinking because the characteristics of mathematics are a science and human activity, namely that mathematics is a pattern of thinking, a pattern of organizing logical proof, which uses carefully defined terms, clear, and accurate [1]. Thinking ability in mathematics learning activities can be classified as follows, namely low-level thinking skills and high-level thinking skills.
High-level thinking skills are related to assumptions about thinking and learning. The relationship is in the form of: First, the level of thinking cannot be separated from the level of learning and even interdependence. Second, thinking related to the content of subject matter in real life that will help learn high-level thinking skills. Third, high-level thinking involves various thought processes that are applied in complex situations and have many variables [2].

Critical thinking skills belong to a group of high-level thinking abilities. Critical thinking is the ability to process, evaluate, and use the information to find logical solutions. In general, not everyone is born in this world has a high level of thinking ability (critical thinking) is also rarely taught in schools. Christian thinking can also be said as reasoned and reflective thinking by emphasizing decision making about what to believe or do. Examples of critical thinking skills, including: (1) compare and differentiate, (2) make categories, (3) examine small parts and whole, (4) explain why, (5) make sequences/sequences, (6) determine the trusted sources, and (7) make predictions.

From the explanation in the paragraph above, it can be shown in the results of a study conducted by Hedi Budiman with his research (2011) in one of the high schools. Hedi compared two high-level abilities namely creative thinking ability and critical thinking skills. In the study, Hedi conducted two trials (written tests), namely before treatment and after treatment. Hedi said that before being given the treatment the average value of the two abilities had a value carried by completeness standards, namely the value of creative thinking ability with a value of 30% and the value of critical thinking skills with a value of 20.56% (referred to as the experimental class). Values obtained by students (control class) for the ability to think creatively and think critically with an average value, namely; to think creatively 26.04% and think critically 20.56%.

The results obtained by students after the pretest were concluded that the average mathematical thinking ability of the experimental class and the control class had no difference, all of them were carried out in the low category (Gain). Hedi conducted a second test after giving treatment using the next problem-based learning approach called the posttest test.

The average value obtained by students in the second test is as follows: in the experimental class the average value of both abilities, namely creative thinking the value is 11.33 or 70.83% and critical thinking 8.10 or 67.50%, and classes that are not given treatment (control) with an average value of ability, namely thinking Creative 8.13 or 50.83% while thinking critically 5.97 or 49.72%.

The results of the research conducted by Hedi can be concluded that the two most dominant abilities are creative thinking skills in the high category, while critical thinking skills are in the moderate category compared to the posttest results conducted in one of the high schools.

If critical thinking is developed, a person will tend to seek the truth, think openly and be tolerant of new ideas, can analyze problems well, think systematically, curiously, mature in thinking, and can think critically independently [3].

Problem-based learning in principle students is faced with various situations or problems that can drive them to get to know mathematical objects, the involvement of students is asked to do the doing math process actively, restating mathematical ideas in shaping new understandings. Thus, the tendency for increased mathematical critical thinking skills to become more open. The choice of problems given to students in problem-based learning plays an important role, because with good problems can optimize the learning process of students in understanding mathematics.

Taking into account the results of research conducted by Hedi in one of the upper middle class and severe expert opinion, the researcher is interested in conducting research in one of class X High Schools entitled "Improving Student Learning Outcomes by Using Mathematical Critical Thinking Ability through Problem Based Learning". The purpose of the study is to examine the improvement of critical thinking skills in students who have problem-based learning with students who get conventional learning.
2. Methods
2.1. A subsection Type and Design of Research
This type of research is quantitative research conducted in the form of experiments, designed using nonequivalent group-control patterns. This pattern is used because the sampling is not done randomly. Sampling is based on classrooms that have been determined by the school, researchers only adjust to existing classes. This research design is referred to as quasi-experimental [4].

Before being given treatment and after needing each group was given a test in the form of pretest and posttest mathematical critical thinking skills (O). The self-determination scale is given to each learning group only at the end of the learning implementation (O*). Classes that apply problem-based learning are referred to as the experimental group (X), while classes that apply direct learning are called control groups.

2.2. Population and Samples
The population in this study was grade X students in one high school. Thus, the sample in this study is 2 classes, one class as an experiment and one class as a control. The study was conducted at one of the High Schools in Ternate City, North Maluku Province, Indonesia.

2.3. Research procedure
There are two stages in the procedure of research carried out, namely preparation and implementation. In full, the description of the research procedure is explained as follows:

Preparation and Implementation.
After the problem is formulated, the next step is to develop research instruments and learning tools, then validate it for further improvement in several ways. After the trial results are obtained, the analysis is carried out to obtain a good picture of the instruments and devices for subsequent use during the study.

This research was conducted at a school that was previously chosen as a research location. Conducting observations to the school which is used as a place of research. During the observation, through discussions and considerations conducted by the mathematics subject teacher and the school, the experimental group and the control group were determined as the research sample.

2.4. Data processing
The results of tests of mathematical critical thinking skills are analyzed quantitatively using statistical tests. To determine the statistical test, the normality and homogeneity of variance are first tested. Calculate the amount of improvement in students' mathematical critical thinking skills using normalized gain developed by Hake (1998). With the formula:

$$\text{Normalized Gain (g)} = \frac{\text{posttest score} - \text{pretest score}}{\text{ideal maximum score} - \text{pretest score}}$$  \hspace{1cm} (1)$$

with gain index criteria:

| Normalized Gain Score (g) | Interpretation |
|--------------------------|----------------|
| $g < 0.30$               | Low            |
| $g \geq 0.70$            | High           |
| $0.30 \leq g < 0.70$     | Is being       |

Calculate descriptive statistics of pretest scores, posttest scores, and g scores that include average scores. Furthermore, quantitative data are analyzed through inferential statistical analysis, using independent sample t-tests.

3. Results and Discussion
To test the hypothesis, it is first checked whether the data obtained is normally distributed and has homogeneity of the data or not. Data obtained in the form of quantitative data derived from pre-test
results and post-test results from both learning. In the analysis, the two data will be seen normality, homogeneity and conduct a comparison test by taking into account the results of the t-test.

3.1. Normality Test
The test results are presented in table 2.

| Kategori          | Statistic | df | Sig. | Statistic | df | Sig. |
|-------------------|-----------|----|------|-----------|----|------|
| Skorngain Konvensional | .144      | 38 | .046 | .905      | 38 | .004 |
| PBM               | .131      | 38 | .100 | .957      | 38 | .157 |

Based on the results of normality testers using SPSS, that data from the pre-test results and the post-test results depicted in the Normalized Gain have the normality shown in table 2. The value (sig.) Of the gain of critical thinking ability using problem-based learning and conventional learning is greater than the value of α = 0.05 so that the gain data can be said to be normally distributed.

3.2. Homogeneity test.
Homogeneity test results are presented in Table 3.

| Kategori                                | Statistic | df1 | df2          | Sig. |
|-----------------------------------------|-----------|-----|--------------|------|
| Skorngain Based on Mean                 | 2.624     | 1   | 74           | .110 |
| Skorngain Based on Median               | 2.840     | 1   | 74           | .096 |
| Skorngain Based on Median and with adjusted df | 2.840 | 1   | 73.370       | .096 |
| Skorngain Based on trimmed mean         | 2.768     | 1   | 74           | .100 |

Based on the results of homogeneity testers using SPSS, that data from the pre-test results and the post-test results depicted in the Normalized Gain have the homogeneity seen in table 3 above. The value (sig.) For normalized gain values in mathematical critical thinking skills for both learning is problem-based learning and conventional learning is greater than the value α = 0.05. In conclusion, both models have homogeneous classes from the same population.

3.3. Hypothesis testing
The results of the t-test can be presented in table 4.

| F           | Sig. | t    | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
|-------------|------|------|----|-----------------|-----------------|-----------------------|-------|-------|
| Skorngain   |      |      |    |                 |                 |                       |       |       |
| Equal Variances assumed                   | 2.624 | .110 | -5.698 | 74 | .000 | -.216 | .038 | -.291 | -.140 |
Based on the normalized Gain hypothesis testing results shown in table 4 above. It was concluded, problem-based learning and conventional learning can improve students' mathematical critical thinking skills. Obtained t-test results of -5.698 and the value of sig. (2-tailed) is 0.000 with α = 0.05. To see a comparison between problem-based learning and conventional learning can be presented in table 5.

| Skorngain | Konvensional | PBM |
|-----------|--------------|-----|
| N         |   38         | 38  |
| Mean      |   .48        | .69 |
| Std. Deviation | .151     | .178|
| Std. Erros Mean | .024     | .029|

By comparing the two learning models, namely problem-based learning and conventional learning can be seen in the average value of Normalized Gain. Table 5 illustrates that the average value of the Normalized Gain for conventional learning is 0.48 and problem-based learning is 0.69. The results showed that students who obtained a problem-based learning model were significantly different from students who received conventional learning. The treatment given gives an effect of 0.69 for problem-based learning. For conventional learning has an effect of 0.48. Compared to the two models, the more influential is the problem-based learning model.

### 4. Conclusions

That is applying the problem-based learning model can improve students' mathematical critical thinking skills (the results of statistical tests conducted by the t-test for independent samples). Statistical test results illustrate that the value of the t-test results was -5.698 with a sig. (2-tailed) value of 0.000 with an α of 0.05. In conclusion, there is an increase in students' mathematical critical thinking skills.
5. References

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