Experimentation of Problem-Based Learning Model on Critical Thinking Ability in Learning Number Theory

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Abstract. Critical thinking is needed in learning mathematics because it can train students to develop and analyze problems given. The research aims to determine the effect of PBL models on critical thinking skills in learning number theory. The research experimental design used was the one-group pretest-posttest. The subjects of this research are students of the Mathematics Education Muhammadiyah University of Metro who had taken the learning number theory. The instrument in this research was a critical thinking test. Data analysis techniques used in this research were (1) normality test using the Liliefors test, (2) homogeneity test using Bartlet test, and (3) hypothesis testing using paired mean difference test. Based on the results of data analysis, it can be concluded that: (1) There is an effect of PBL model on students' critical thinking skills, (2) There is a difference in the average N-Gain score of students' critical thinking skills before and after using PBL with observed = 12.025 > t_critical (0.05; 1) = 2.001., (3) PBL can increase in the average value proportion of each indicator of critical thinking.

Keywords: Critical Thinking, Number Theory, Problem-based Learning.

1. Introduction

In learning number theory, many discussions focused on critical thinking problems. So far, students still often find difficulties when asked to solve critical thinking problems[1]. Critical thinking is of very importance at both school and university levels [2]. It is stated that critical thinking skills are an effective way to improve the cognitive skills to improve students' mathematical concept understanding because the skills can help them interpreting, analyzing, evaluating, and presenting logically and sequentially [2-3]. Critical thinking is part of higher-order thinking skill ability refers to analyze, evaluated and create [4-5]. All students can improve and expand their critical thinking during mathematics learning. Students can develop this ability in facing math problems, identifying possible solutions, and evaluating the results of their work, thus, allowing them to become critical thinkers [7]. Critical thinking is needed in learning mathematics because it can train students to develop and analyze problems given.

The critical thinking indicators used in this research are (1) focus, (2) reason, (3) inference, (4) situation, (5) clarity, and (6) overview. The description of each indicator is: (1) focus is able to categorize information about the problem (write the known and the questioned), (2) reason is able to write the formula to be used in a complete and systematic manner, (3) inference is able to complete the
algebraic process to get the right answer, (4) situation is able to match the answers obtained correctly with the conditions of the problem, (5) clarity is able to provide a complete argument to draw conclusions, and (6) overview is able to do the algebraic process completely to double-check the answers obtained correctly.

To be able to achieve optimal critical thinking skills, the right learning model is needed [8, 9]. The learning model used must be able to familiarize students to be able to solve critical thinking questions. One of the learning models that can be applied in number theory learning is the Problem-Based Learning (PBL) learning model. PBL is active learning that involves students by giving problems to be solved correctly [10–12]. Questions given to students are a problem in everyday life by providing problems in the real world context; this can help students to develop concepts independently [13]. With the existence of PBL that creates active learning, then this can help students to solve critical thinking problems because students are accustomed to building concepts independently.

At the problem orientation stage, students are not accustomed to understanding the material by first solving the given problem. Students are more accustomed to presenting content directly. So when given an article that begins with a question, students feel they have not been able to solve critical thinking problems correctly [14]. From the results of this research, it appears that students are still challenging to get used to changing the habit of how to solve problems in a direct way to use PBL.

PBL model learning syntax seen in learning activities students can train and develop high order thinking student skills because students gain experience directly and can change behavior (knowledge, skills, attitudes) both in terms of quantity and quality [15]. PBL can train students to develop further and improve their critical thinking skills. This can be caused by students being able to discover the concepts of number theory learned independently. Here are five stages of PBL, namely : (1) student orientation to the problem, (2) organizing students to learn, (3) guiding individual and group investigations, (4) developing and presenting data, and (5) analyzing and evaluating problem-solving processes [16]. Problem-based learning has stages that support critical thinking skills, especially at the scene of conducting investigations and developing problems. Following are the steps of PBL in the research based on the opinion of Duksri et al, syntax of PBL Learning are : (1) Orientation to the problem, (2) Organizing to learn, (3) Guiding individual and group investigations, (4) Developing and presenting data, and (5) Analyzing and evaluating problem-solving processes.

From the background of the problem, it is necessary to implement problem-based learning to improve students’ critical thinking skills in number theory. The research aims were of this research were to determine the effect of PBL models on essential skills of thinking in learning number theory. The benefits of this research are as references that can be used as variations in learning models in number theory. This research has a novelty to the object of research used is the learning of number theory.

2. Method
The subjects of this research were students of Mathematics Education Muhammadiyah University of Metro following learning number theory. This learning was attended by 25 students. The learning model used in this research is the Problem-Based Learning model that functions as an independent variable. The dependent variable used in the research is a critical thinking ability.

The instrument in this research was a critical thinking test item consisting of six indicators: (1) focus, (2) reason, (3) inference, (4) situation, (5) clarity, and (6) overview. Data analysis techniques used in this research are (1) normality test using the Liliefors test, (2) homogeneity test using Bartlet test, and (3) Hypothesis Testing using paired T-Test Mean Difference. N-gain tests are used to see the effect of PBL on critical thinking skills.

3. Result
This research was conducted at the beginning of March 2019. The subjects of this research were 25 students of Mathematics Education FKIP Muhammadiyah University Metro. At the beginning of learning number theory, the lecturer gives a preliminary test of the problem of critical thinking skills
that were carried out to determine the initial abilities of students. From the results of these tests obtained the initial average value of students ‘critical thinking skills of 52.

At the pretest, the value of students’ critical thinking skills was only 52, and there was a problem in the indicator of identifying the problem (focus), analyzing the solution (inference), and concluding correctly (inference). Besides, students also were not been able to test the results obtained (general description). With the average value proportion of each indicator, namely: 1) focus of 0,14; (2) reason of 0,10; (3) inference of 0,11; (4) situation of 0,11, (5) clarity of 0,12 and (6) overview of 0,04. Indicators critical thinking skill including (1) interpretation is the ability to understand or express the meaning of the data or situation presented in a problem mathematics; (2) analysis, namely ability identify the relationship between data given and reasoning given arguments; (3) evaluation, namely the ability to find and prove a mistake in a mathematical problems; (4) decisions namely the ability to draw conclusions from one mathematical problems [7].

Indicators of critical thinking skill including (1) interpretation, it is the ability to understand or express the meaning of the data or situation presented in a mathematics problem; (2) analysis, namely ability to identify the relationship between data given and reasoning embedded arguments; (3) evaluation, namely the ability to find and prove a mistake in a mathematical problems; (4) decisions, namely the ability to draw conclusions from one mathematical issues [17]. The critical thinking indicators, namely: (1) determining the information given, (2) choosing and justifying strategies to solve problems[18]. After conducting an initial test of critical thinking skills, then the number of theory learning is carried out using the PBL model. At the end of the use of the PBL model, students are given a final test to see N-Gain of critical thinking skills.

The result of normality test was obtained: (1) the average pretest score is 52, standard deviation is 13,5 with \( L_{\text{observed}} = 0.121 < L_{\text{critical}} (0.05; 2) = 0.177 \) and test decision \( H_0 \) accepted , (2) average posttest is 68, deviate standard is 8,3; value is \( L_{\text{observed}} = 0.130 < L_{\text{critical}} (0.05; 2) = 0.177 \) and test decision declared that \( H_0 \) was accepted. From the results of this normality test, it can be seen that the pre-test and post-test of the critical thinking abilities were normally distributed. After the normality test had been done, the next step was to do a homogeneity test using the Bartlet formula.

The result homogeneity test was obtained: the value of \( X^2_{\text{observed}} \) was 5,440 and value of \( X^2_{0.05; 2} \) was 5,991 and the test decision declared that \( H_0 \) was accepted. It appears that the PBL class is homogeneous. Homogeneity test results indicate that the initial value and final value of critical thinking skills of students after using PBL have the same variance. After obtaining normal and homogeneous data, the hypothesis test is then performed using the two average similarity test.

The N-Gain Hypothesis test result obtained: average N-Gain was 15,28; the standard deviation was 1,27; the value of \( t_{\text{observed}} \) was 12,025, the value of \( t_{\text{critical}} \) was 2,001 and test decision declared that \( H_0 \) was rejected. Based on Table 3, it can be seen that \( t_{\text{observed}} = 12,025 > t_{\text{critical}} (0.05; 1) = 2,001 \); the results of the hypothesis testing declared that \( H_0 \) was rejected. It can be concluded that there were differences in the N-Gain of students’ critical thinking skills before and after learning using PBL.

4. Discussion

From the results of the hypothesis test in Table 3, it can be seen that there are differences in the students’ N-gain values before and after PBL learning. The average initial value of students’ thinking abilities is 52. After applying the PBL model in learning number theory, an increase in the average value becomes 68 with \( t_{\text{observed}} = 12,025 > t_{\text{critical}} (0.05; 1) = 2,001 \). This increase can occur because one of the advantages possessed by PBL is that it can encourage students to research and define the problem given. The problem-based learning process, a teacher, only acts as a facilitator by orientation to the problem to students. In learning, the teacher motivates students to be actively involved in finding problem-solving, arranging students to research, define, and organize tasks related to the problem [19]. In this research, the teacher facilitates students with critical thinking questions in group discussions. So, students can be active in solving critical problems.

At the step of presenting these results, there is a process of checking (clarity), and testing of the results (overview) obtained. This step can optimize the curiosity for students if there are still problems
that cannot be understood. The question of students' critical thinking skills at the reason, clarity, and overview indicators students have not been able to focus (focus) and plan reasoning solutions from problem given [20]. The critical thinking step starts by focusing on the question of identifying the problem well, finding out what the real question is and how to prove it. Next, formulate arguments that support conclusions, look for evidence that supports the reasons for an end so that findings can be accepted or in other words, the ideas given must and following results [21].

In learning number theory using PBL, students are more accustomed to solving the given questions. The question and answer process at the stage of conducting an investigation more better than early learning. At this stage, students to ask questions in their groups when some material or questions are difficult. Besides, at the stage of presenting the results of group discussions, there have been several students from other groups want to ask questions. So that at the stage of presenting the results of the discus, a question and answer can occur that is quite interactive. After learning number theory using PBL, the final average value of students' critical thinking skills was 68. With the average value proportion of each indicator, namely: 1) focus of 0.19; (2) reason of 0.14; (3) inference of 0.13; (4) situation of 0.15, (5) clarity of 0.15 and (6) overview of 0.10. The following is Figure 1 — the average proportion value of students' ability in learning number theory using the PBL model.

![Histogram of the Average Proportion Value of Critical Thinking skill](image_url)

Figure 1. Histogram of the Average Proportion Value of Critical Thinking skill

From Figure 1., there is an increase in students' thinking ability after using the PBL model. In the PBL model, there are steps to develop the data provided. From this stage, students are allowed to discuss and find independently solving problems about critical thinking problems. At the discussion stage, students can learn from each other to be able to carry out reasoning analysis correctly. Besides, the steps to present the results of the settlement to different groups can be a means of creating interactive questions and answers. At the stage of showing these results, there is a process of checking (clarity), and testing of the results (overview) obtained. This step can optimize the curiosity for students if there are still problems that cannot be understood. Students have not been able to focus (focus) and plan reasoning solutions from the question given. This results in students not being able to find concepts and solve problems given. Besides, students not to be able to perform indicators of checking back (clarity) and testing again (overview) [15].

The Problem-based Learning learning process was more emphasized on students' ability to analyze the problems given so that the Problem-based Learning model had advantages over the lecture model.
PBL model has the advantage of being able to encourage students to analyze problems so that students’ abilities can be improved. Increased critical thinking skills in PBL learning can be due to students getting used to solving problems of critical thinking skills. In PBL learning, students begin with being given critical thinking problems. Then the question is discussed in each group to be resolved.

The critical thinking step starts by focusing on the problem of identifying the problem well, finding out what the real question is and how to prove it. Next, formulate arguments that support conclusions, look for evidence that supports the reasons for an end so that findings can be accepted or in other words, the ideas given must and following results.

Critical thinking is essential for mathematics learning, including number theory. PBL learning steps also support indicators of critical thinking. From the implementation of the PBL model, it can be seen the magnitude of the increase in the average critical thinking skills of students in learning number theory.

5. Conclusion and Suggestion

Based on the results of data analysis, it can be concluded that: (1) There is an effect the PBL model on students’ critical thinking skills, (2) There is a difference in the average N-Gain score of students' critical thinking skills before and after using PBL with $t_{\text{observed}} = 12.025 > t_{\text{critical}} (0.05; 1) = 2.001.$, (3) PBL can increase in the average value proportion of each indicator of critical thinking.

Suggestions were given for further researchers, namely: (1) Prepare critical thinking questions to overcome signs checking back (clarity) and testing the results obtained (overview), (2) Perform PBL learning variations so that they don't feel monotonous.

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