Comparison of mathematical thinking through problem based learning at university of jember

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Abstract. In the understanding concepts and the thinking mathematically in studying statistics is necessary managed the learning process that easily understood by students. One model that can be applied is the Problem-based Learning (PBL) learning model. This research compared PBL and conventional learning models to students’ mathematical thinking skills. The subject of research is the student in the third semester of Economics Education Study Program at the University of Jember Academic Year 2018/2019. The design used in this study is matching pretest-posttest control group design. The design of this study was used because the study involved two classes. The experimental class is the class that has the application of the PBL Model, and the control class is the class taught using the Conventional Learning Model. The test is done twice, namely before the learning process (pretest) and after the learning process (posttest). The results obtained from this study are hypothesis testing from the t-test resulting in t-count value of 5.475 and t-table of 2.378 thus the t-test > t-table or 5.475 > 2.337. It can be concluded that there is a difference between the application of PBL and conventional learning to students’ mathematical thinking skills. A difference is seen from the mean of the two learning models, namely the overall mean of the PBL model is 84.28 and the mean of the conventional model is 72.78. So it can be concluded that the PBL model is better than the conventional model.

1. Introduction

In this era of globalization, the development of science and technology is very rapid. This encourages everyone to be able to compete globally. However, it cannot be denied that the existence of someone in this world is greatly influenced by the existence of human resources. Continues to strive to improve education in the community, with this created human resources who have logical and mathematical thinking. It cannot be denied that not all successful people are mathematicians, but everyone can succeed if they are able to think mathematically.

Education has a very central role in improving the quality of human resources. The change in current educational orientation by placing students at the center of attention requires lecturers to be more creative in managing learning activities. Lecturers are required to be able to shift the emphasis of learning activities from what materials students will learn to how to enrich the learning experience of students. One way that can be done to achieve this goal is to develop educational programs that focus on developing thinking skills. The development of these capabilities can be done through mathematics which can substantially encourage the development of student thinking skills. Because mathematical concepts are arranged hierarchically, structured, logical, and systematic, starting from the simplest
concepts to the most complex concepts that require good mathematical thinking skills to overcome them.

Harel [6] described the distinction between ways of thinking and ways of understanding contexts of initial research, centralized, often interrelated, mathematical activities: 1. Comprehension of mathematical content, as when reading texts or listening to others. 2. Carrying out an investigation, as when solving a problem. 3. Establishing truth, as when justifying or refuting.

Adler and Milne [1] define Problem-based Learning as a method that focuses on identifying problems as well as compiling an analysis and solving framework. This method is done by forming small groups, lots of cooperation and interaction, discussing things that are not or are poorly understood and share roles to carry out tasks and report to each other.

The Problem-Based Learning model is a student-centered learning model and supported the constructivist learning theory [4]. This agrees with Hoffman dan Ritchie [8] defining problem-based learning as a student-centered pedagogical strategy that reflects significant, contextual, real-world, unstructured that facilitates resources, guidance, instruction, and opportunities for reflection when students develop knowledge and problem-solving skills.

This PBL model is recommended to be applied in the world of education. Duch et al. [3] state that this model has the ability to do the following: 1) improve critical thinking skills and be able to analyze and solve problems related to the real world; 2) looking for, evaluating, and using the right resources in the learning process; 3) work cooperatively in teams and small groups; 4) demonstrate communication skills effectively and efficiently, both oral and written; and 5) using the content of intellectual knowledge and skills in the learning process.

Seng [9] states that Problem-Based Learning in the curriculum at least contains the following characteristics, namely (1) the problem is the starting point of learning, (2) the problem usually relates to real situations, (3) problems usually generate many views or perspectives (4) problems that challenge current knowledge, behavior and competence of students, (5) prioritize self-regulated learning, (6) utilize various sources, (7) collaborative, communicative, and cooperative learning, (8) develop inquiry abilities and student problem solving, (9) synthesis and elaboration at the end of learning, and (10) evaluation and review of student learning experiences and learning processes.

In line with the above opinion, Sockalingam and Schmidt [10] states that the characteristics of PBL are (1) the extent to which the problem leads to the intended learning problem, (2) the interest triggered by the problem, (3) the format of the problem, (4) the extent the problem encourages critical reasoning, (5) the extent to which the problem emphasizes independent learning, (6) problem clarity, (7) difficult problems, (8) the extent to which the problem is relevant; namely valid and useful, (9) the extent to which the problem relates to students' initial knowledge, (10) the extent to which the problem stimulates elaboration, and (11) the extent to which the problem emphasizes teamwork. According to Arends [2], PBL is designed primarily to help students develop thinking skills, problem-solving skills, and intellectual skills. The purpose of the problem in PBL is to know the content (content) of a particular scientific discipline, multidisciplinary learning, and obtain problem-solving skills and learning skills.

Based on the characteristics described, problem-solving is the focus of learning using the PBL model. The problem to be solved is authentic. This is in accordance with the opinion of Graft and Kolmos [5] which states that "PBL is a learning method that starts student learning by creating the need to solve authentic problems". Authentic problems are used as stimuli in learning. These problems are the main capital that can encourage students to collect information in solving problems. By using authentic problems, students can associate learning the material with the real world that occurs in the surrounding environment, so that learning is more meaningful. The syntax or stages of the Problem-Based Learning (PBL) model according to Arends [2] are shown in Table 1.
Table 1. The syntax of problem-based learning (pbl) model

| Phase    | Lecturer Behavior                                                                 |
|----------|-----------------------------------------------------------------------------------|
| Phase 1  | Orient the problem to students                                                     |
|          | The lecturer discusses learning objectives, describes various important logistical needs, |
|          | and motivates students to be involved in problem-solving activities.               |
| Phase 2  | Organizing students to understand Research problems and plan their Completion       |
|          | Lecturers help students to define and organize learning tasks related to the problem.|
| Phase 3  | Helps independent or group investigations                                           |
|          | Lecturers encourage students to get the right information, carry out experiments and find solutions.|
| Phase 4  | Develop and present a solution and presentation model                              |
|          | Lecturers assist students in planning and preparing materials for presentations and discussions, such as reports, videotapes and helping them prepare presentations.|
| Phase 5  | Analyze and evaluate the problem-solving process                                   |
|          | The lecturer helps students reflect on the investigation process and other processes used in solving problems.|

Haruna, et al [7] found that through motivation can be increased to encourage them to reach deep learning. Students’ responses about motivation they are through the course are included to demonstrate the impact of motivation toward learning processes in PBL.

For the college level, statistical material that is part of mathematics is increasingly difficult to learn. The statistics is mathematical learning that judged negatively by students and they have considerable difficulties with some mathematical processes such as reasoning and problem-solving. One of the subjects that require thinking is a statistical course. The statistics course is one of the subjects that must be taken by the Economics Education Study Program students with a weight of 4 credits. Statistics courses study the introductory theory, of statistics statistical functions in research, presentation of data, size of central tendency, size of location, size of distribution, assumption test, population and sample, hypothesis testing, difference test with t-test and analysis of variance, correlation and regression, analysis partial, nonparametric statistics, such as: chi-square, sign test, binomial, Wilcoxon test, Kolmogorov Smirnov test, and others. In studying the subject, a problem-solving process is carried out. Therefore, understanding concepts are needed and solving problems in everyday life.

Referring to the background above, the problems studied in this study can be formulated into the following sub problems. Are there differences in the increase in mathematical thinking skills of groups of students who follow PBL and conventional learning? Subsequently, the following research hypotheses are proposed. Mathematically, between students who get PBL and conventional learning. For the purposes of this study, the above hypothesis is then tested and analyzed with inferential statistics to obtain more detailed research results.

2. The Method

This study was categorized into quasi-experimental, research which is a research method implemented and planned by researchers to collect evidence that has to do with the hypothesis, however, the sampling in this study was not done in a full randomize. Used in this study are matching pretest-posttest control group design. The research design looks like the following:
Table 2. Research design

| Group     | Pre-test | Treatment of | Post Test |
|-----------|----------|--------------|-----------|
| Experimental | Q₁       | X            | Q₂        |
| Control   | Q₁       | Y            | Q₂        |

Information:
Q₁: Pre-test
Q₂: Post-test
X: Treatment with Problem-based Learning (PBL) learning model.
Y: Treatment with conventional learning models.

This research is planned to be carried out at the University of Jember’s Economic Education Study Program. The research population is all third-semester students. The sample from the population was chosen by two classes as the experimental class and the control class. Treatment was given to the two samples. The treatment using the PBL model was given in the experimental class and the Conventional Learning model was given to the control class. Data collection techniques in this study were given by pretest and posttest. The pretest is given when students have not been given treatment, while posttest is given after being given treatment to students. The scores on both tests are the data that will be analyzed. The free sample t-test was used to compare the average of two independent case groups. To facilitate calculations, the t-test in this study was carried out with the help of Statistical Product and Service Solutions (SPSS) software. The criteria for students’ critical thinking skills are presented in the following Table 2:

Table 3. Categories of Mathematical Thinking Ability

| Interval Percentage of Student Mathematical Thinking Ability in Statistics Courses | Category |
|----------------------------------------------------------------------------------|----------|
| 80 - 100                                                                         | Very good|
| 66 - 79                                                                           | Good     |
| 56 - 65                                                                           | Enough   |
| 40 - 55                                                                           | Less     |
| 0 - 39                                                                            | The least|

3. Results and Discussion

Based on the results of student statistical learning, problem-based learning model learning is said to be effective. The Effectiveness of Learning PBL Model is shown by student statistical learning outcomes in simple linear regression analysis material in terms of the level of ability of students who were originally in the good category to be a very good category. Mathematical thinking in the classroom experiment applies PBL, the value of pretest 68.23 and the posttest value reaches 84.28. The control class has the value of pretest 70.66 and the posttest value reached 72.78. The difference mean pre-test and post-test of the two classes is presented in the following Figure 1.
The results obtained from this study are hypothesis testing from the t-test resulting in $t_{test}$ of 5.475 and $t_{table}$ of 2.378 thus the $t_{test}$ > $t_{table}$ or 5.475 > 2.337. It can be concluded that there is a difference between the application of PBL and conventional learning to students' mathematical thinking skills. The value of $t_{test}$ the experimental class is shown in the following Figure 2.

Figure 2. Independent Sample T of the experimental class

Meanwhile, mathematical thinking of students who obtain the PBL learning model is more excellent than the ability to think mathematically in students who get conventional learning that is classified as good. Increased values in the experimental class and control class are shown in Figure 2. Figure 2 shows that there was a significant increase in the experimental class which applied PBL to the pretest and posttest values.

The results of this study indicate that student statistical learning outcomes taught by PBL model learning in terms of the level of student ability are in a very good category with completeness reaching 94.74 % and student knowledge shows a significant increase after applied problem-based learning model learning. This is evidenced by the average student statistical learning outcomes of 84.28 with a standard deviation of 6.833 from the ideal score of 100.

Overall, PBL model learning can improve students' ability to understand simple linear regression material, this is indicated by student classifications with the value that results in student learning is in a very good category. By learning PBL models, students are more eager to learn statistics. The application of PBL model learning in statistical learning in the classroom provides an opportunity for students to submit an answer problems based on the given situation.

Based on the results of the study it can be concluded that there is an increase in the ability to think mathematically about students according to the expected indicators. 1. Comprehension of mathematical content, as when reading texts or listening to others. 2. Carrying out an investigation, as when solving a problem. 3. Establishing truth, as when justifying or refuting. The application of PBL is able to improve students' mathematical thinking skills in the experimental class. On the other hand, the achievement of the ability to think mathematically of students who apply PBL is better than students who apply conventional learning. This shows that statistical learning with conventional approaches is not effective in terms of students' mathematical thinking abilities.

Problem number 3 is used to measure the mathematical ability of the first indicator students, namely the Comprehension of mathematical content, as when reading texts or listening to others is presented in Figure 3. The differences in answers between students in the control class and...
Experimental class can be seen from the control class as in Figure 3 (b) it can be seen that students have not been able to explain the meaning of the objectives and the main assumptions of simple linear regression analysis properly and correctly. While the answers to the experimental class students as in Figure 3 (a) have been able to provide an explanation of the meaning, objectives and main assumptions of simple linear regression analysis properly and correctly, although there are still disadvantages in terms of language.

Figure 3. Differences in answers between students: (a) the experimental class and (b) the control class

Measurement of mathematical thinking ability for the second indicator, namely Carrying out an investigation, as when solving a problem is done with question number 4 (Figure 4). Differences in student answers to working on question number 4 in the control class and experimental class on problem solving indicators can be seen in student answers in the control class as in Figure 5 (b) we can see that students have been able to write formula correlation coefficients and regression equations but cannot answer correctly in calculating the correlation coefficients and regression line equations. Meanwhile, for the answers of students in the experimental class in figure 5 (a), we can see that students have been able to write the formula of the correlation coefficients and regression equations in the questions and calculate the correlation coefficients and regression line equations then do the math calculations completely and correctly.
Figure 4. Problem 4 for student worksheets

Figure 4 shows the problem for measuring indicators of carrying out investigation as when solving a problem.

Figure 5. The student's answer for second indicators: (a) the experimental class and (b) the control class

To measure the ability of indicators establishing truth, as when justifying or refuting is given a question 5 presented in Figure 6. Differences in answers of students in the experimental class and control class
in the third indicator can be seen in Figure 6, student answers to the control class as shown in Figure 6 (b) We can see that students have been able to explain how to prove the truth of Keynesian theory but have not been able to show the justification of the theory with statistical results that are mathematically reasonable and correct. Student answers to the experimental class as shown in Figure 6 (a), we can see from student responses that students are able to use mathematical models from statistical results as a basis for determining their justifications properly, correctly and completely.

Figure 6. The student's answer for third indicators: (a) the experimental class and (b) the control class

4. Conclusions

Based on the formulation of the problem and research objectives and the results of the research and discussion obtained as described, the conclusions that can be drawn from this study are that in general, the use of PBL learning models has a positive impact on the mathematical thinking ability of Jember University economic education students. After PBL model learning has been applied, the level of students' abilities that were originally in the good category became a very good category. Mathematical thinking in the experiment class that applies PBL with the interpretive value of 68.23 and the posttest value reaches 84.28 for the control class; the pretest value is 70.66 and the posttest value reaches 72.78. Meanwhile, mathematical thinking of students who obtain the PBL learning model is relatively good rather than mathematical thinking ability in students who get conventional learning that is classified as good.

The results of this study indicate that the statistical learning outcomes of students taught by learning model problem-based learning in terms of the level of ability of students are in a very good category with completeness reaching 94.74% and student knowledge shows a significant increase after applied problem-based learning. This is evidenced by the average student learning outcomes of 84.28 with a standard deviation of 6.833 from the ideal score of 100
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