The effectiveness of problem-based learning on students’ problem solving ability in vector analysis course

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Abstract. The student's low ability in mathematics problem solving proved to be the less effective of a learning process in the classroom. Effective learning was a learning that affects student’s math skills, one of which is problem-solving abilities. Problem-solving capability consisted of several stages: understanding the problem, planning the settlement, solving the problem as planned, re-examining the procedure and the outcome. The purpose of this research was to know: (1) was there any influence of PBL model in improving ability Problem solving of student math in a subject of vector analysis ?; (2) was the PBL model effective in improving students' mathematical problem-solving skills in vector analysis courses? This research was a quasi-experiment research. The data analysis techniques performed from the test stages of data description, a prerequisite test is the normality test, and hypothesis test using the ANCOVA test and Gain test. The results showed that: (1) there was an influence of PBL model in improving students’ math problem-solving abilities in vector analysis courses; (2) the PBL model was effective in improving students' problem-solving skills in vector analysis courses with a medium category.

1. Introduction
Mathematics learning consists of five content standard mathematics learning process [5]. The five content standard learning process is a mathematical ability that must be owned by a student. Nation Council of Teachers of Mathematics [5] they are: 1) Problem Solving; 2) Reasoning & Proof; 3) Communication; 4) Connections; 5) Representation;

The student’s low ability in mathematics problem solving prone to the less effective of the learning process in the classroom. Effective learning is a learning that affects students math skills, one of which is problem-solving abilities. Polya in Mushlihuddin [4] said that problem-solving abilities consist of several stages: understanding the problem, planning the settlement, solving the problem as planned, Reviewing the procedures and results. Nation Council of Teachers of Mathematics [5] The instructional program of student problem-solving skills should enable each student, they are: 1) Build new mathematical knowledge through problem-solving; 2) Solve problems that arise in mathematics and in other contexts; 3) Apply and adapt a variety of appropriate strategies to solve problems; 4) Monitor and reflect on the process of mathematical problem solving.

One of the learning model that can solve the problem one of them is PBL (Problem Based Learning) model. Problem-Based Learning (PBL) model describes a learning environment where problems drive the learning. That is, learning begins with a problem to be solved, and the problem is posed in such a way that students need to gain new knowledge before they can solve the problem.
Rather than seeking a single correct answer, students interpret the problem, gather needed information, identify possible solutions, evaluate options, and present conclusions. Proponents of mathematical problem solving insist that students become good problem solvers by learning mathematical knowledge heuristically [2].

Arends [1] there are five stages in the syntax of problem-based learning, they are: 1) Provide orientation about the problem to students; 2) Organizing students to research; 3) Assisting independent and group investigations; 4) Develop and present artefacts and exhibits; 5) Analyze and evaluate the problem-solving process. The PBL model requires students to be more active. Because in the students' learning is directly involved in the investigation and find the solution of the problem, so in the end, the students are helped to become autonomous students who can help themselves, in solving the problems faced.

Therefore, the researcher was interested to conduct further research on problem-based learning model with the title of the effectiveness of PBL model in the student’s ability mathematics problems solving on Vector analysis.

The purpose of this research was to know: 1) was there any influence of PBL model in improving ability Problem solving of student math in the subject of vector analysis?, 2) was the PBL model effective in improving students' mathematical problem-solving skills in vector analysis courses?

2. Methods and Materials

Determination of the sample by conducting preliminary tests to see the homogeneity of each class. Based on the preliminary tests the researcher assumes that the nine classes are homogeneous, so the researcher concludes taking only one class from eight classes at random (Cluster Random Sampling).

This research was a quasi-experiment research with two research variables. The research design is shown in Table 1.

| Group   | Pre-test | Treatment | Postest |
|---------|----------|-----------|---------|
| Experiment | T₁    | X₁       | T₂      |
| Control   | T₁    | X₂       | T₂      |

Information:
T₁ = pre-test
T₂ = postest
X₁ = experimental group using PBL model
X₂ = control group using traditional model

The procedures in the study are as follows:
1. Early research was given preliminary or pre-test to see the homogeneity of each class of the population, in order to determine the sample class.
2. The researcher gave a pre-test to see the student's initial ability level.
3. The researcher provided a stimulus for the sample class using the problem-based learning model for X₁ and the conventional model for X₂.
4. Provided a post to see the level of success of students' math skills.
5. Conducting hypothesis test with the procedure as follows: 1) test description of data; 2) test data prerequisites; 3) statistical test that is ANCOVA-test to see the influence of PBL model in improving the mathematical ability of the student of Vector Analysis [7], and Gain-test Hake [6] to see the effectiveness of PBL model in improving students math skills Vector analysis.

\[ N_{gain} = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}}. \]

The scoring rate is categorized into three categories, shown in table 2, as follows:
Table 2. Category N-Gain Score

| Category | Information       |
|----------|-------------------|
| High     | \(N_{gain} \geq 0.7\) |
| Medium   | \(0.3 < N_{gain} < 0.7\) |
| Low      | \(N_{gain} \leq 0.7\) |

3. Results and Discussion

3.1. Research Result

Descriptive analysis of pre-test and score resulted from descriptive data. Some descriptive data of and from the results of this study are mean scores and standard deviations shown in Table 3.

Table 3. Descriptive Statistics

| Statistics     | Pre-test        | Post-test       |
|----------------|-----------------|-----------------|
| Mean           | 68.6000         | 82.2571         |
| Standard Deviation | 8.16088      | 7.51212         |

Based on the results of the descriptive analysis shows that the pretest averages for PBL model 68.60, pretest for Conventional model 67.51, post-test for PBL model 82.26, post-test for conventional model 77.46. As for standard deviation pretest model PBL 8.16, pretest for conventional model 6.21, post-test for PBL model 7.51, post-test for conventional model 6.64.

The normality test is a test of the spread of each score on the pre-test score and post-test score, both in the control group and in the experimental group. The scatter normality test scores were performed by Kolmogorov-Smirnov and/or Shapiro-Wilk statistical tests. The results of the scatter distribution normality test are shown in table 4.

Table 4. Tests of Normality

| Model          | Test   | Kolmogorov-Smirnov*  | Shapiro-Wilk  |
|----------------|--------|----------------------|---------------|
|                |        | Statistic df Sig.    | Statistic df Sig. |
| PBL            | Posttest | .114 35 .200         | .970 35 .430  |
| Konvensional   | Posttest | .108 35 .200         | .970 35 .431  |

* This is a lower bound of the true significance.
  a. Lilliefors Significance Correction

Based on normality test results indicate that the value of sig. At Kolmogorov-Smirnov more than 0.05, so the conclusion is good post-test data by using normal distributed PBL model and traditional models.

The homogeneity test of variance was intended to determine the homogeneity of the variance of pretest score between the control group and the experimental group. Likewise, the homogeneity of variance scores post-test between controls and experimental groups. The homogeneity test of variance is shown in table 5.

Table 5. Tests of Homogeneity of Variance

| Test          | Levene Statistic | df1 | df2 | Sig. |
|---------------|------------------|-----|-----|------|
| Pre-test      | Based on Mean    | .587| 1   | 68   | .446 |
|               | Based on Median  | .465| 1   | 68   | .497 |
|               | Based on Median and with adjusted df | .465 | 1 | 64.635 | .498 |
|               | Based on trimmed mean | .610 | 1 | 68   | .438 |
|               | Based on Mean    | .243| 1   | 68   | .624 |
|               | Based on Median  | .257| 1   | 68   | .614 |
|               | Based on Median and with adjusted df | .257 | 1 | 66.217 | .614 |
|               | Based on trimmed mean | .252 | 1 | 68   | .617 |
Based on homogeneity test results indicate that the value of sig. On Levene Statistic over 0.05, it was clarified that the variance of the pretest score between the control group and the experimental group was homogeneous. Likewise, the variance of posttest scores between the control group and the experimental group was homogeneous.

Test slope regression or interaction test is intended to determine whether there is the influence of learning model on learning outcomes. If there is an interaction (p < 0.05) between the regression line of the pretest score and posttest score in the control group with the regression line between the pretest score and posttest score in the experimental group, the student learning outcomes are influenced by other variables instead of the learning model variables. Conversely, if there is no interaction (p > 0.05) between regression line of pretest score and posttest score in control group with regression line between pretest score and posttest score in experiment group, student learning outcomes are only influenced by learning model variable, not by variable another. Interaction test results or homogeneity of the slope of the regression line are shown in Table 6.

| Source            | Type III Sum of Squares | df | Mean Square | F     | Sig. |
|-------------------|-------------------------|----|-------------|-------|------|
| Corrected Model   | 2669.896*               | 16 | 166.868     | 7.699 | .000 |
| Intercept         | 156477.422              | 1  | 156477.422  | 7219.882 | .000 |
| Model             | 245.642                 | 1  | 245.642     | 11.334 | .001 |
| Pre-test          | 2125.462                | 9  | 236.162     | 10.897 | .000 |
| Model * Pre-test  | 104.518                 | 6  | 17.420      | .804  | .571 |
| Error             | 1148.676                | 53 | 21.673      |       |      |
| Total             | 450220.000              | 70 |             |       |      |
| Corrected Total   | 3818.571                | 69 |             |       |      |

a. R Squared = .699 (Adjusted R Squared = .608)

The significance figure for the Model line * Pre-test obtained from the interaction test is 0.571. This significance number is more than 0.05 so it can be concluded that the covariate variable has no significant effect on student learning outcomes. In other words, the variable of student learning outcomes is only influenced by the variables of applied learning model.

After all assumption tests are met, hypothesis testing with ANCOVA statistics. The alternative hypothesis tested is "PBL model can improve students' mathematical problem-solving skills in vector analysis courses." The test results using ANCOVA statistic produce significance value as shown in Table 7.

| Source            | Type III Sum of Squares | df | Mean Square | F     | Sig. |
|-------------------|-------------------------|----|-------------|-------|------|
| Corrected Model   | 2237.240*               | 2  | 1118.620    | 47.395 | .000 |
| Intercept         | 740.047                 | 1  | 740.047     | 31.355 | .000 |
| Pre-test          | 1834.040                | 1  | 1834.040    | 77.707 | .000 |
| Model             | 281.547                 | 1  | 281.547     | 11.929 | .001 |
| Error             | 1581.331                | 67 | 23.602      |       |      |
| Total             | 450220.000              | 70 |             |       |      |
| Corrected Total   | 3818.571                | 69 |             |       |      |

a. R Squared = .586 (Adjusted R Squared = .574)

The above output shows that the influence of student Pre-test and the difference of learning model to the Post-test value obtained by the students simultaneously can be seen from the number of signatures in the Corrected Model. It can be seen that the number of significance is 0.000. Because the value of significance is far below 0.05 then H0 is rejected. So at the level of 95% confidence can be concluded that simultaneously Pre-test students and learning models affect the value of post-test obtained by students.
The significance of the Pre-test variable is 0.000. Because of the value of Sig. <0.05 then H0 is rejected. This means that at the 95% confidence level there can be a linear relationship between the Pre-test and the Post-test value obtained by the student. This statement indicates that the ANCOVA assumption has been met. This test is done by eliminating the influence of differences from the learning model first.

Further testing is done to determine the effect of different learning models to the value of post-test obtained by students. This test is done by eliminating the influence of Pre-test of the learning model. From the results of processing, it can be seen that the significance of the learning model is 0.001. Because the value is far below 0.05 then H0 is rejected. Without the influence of Pre-test, at 95% confidence level there is the influence of learning model difference to the post-test value obtained by the student. So it can be concluded PBL model can improve students’ math problem-solving skills in vector analysis courses. If we look at the posttest average score of the students, it appears that the mean score of the experimental group posttest is higher than that of the control group's posttest mean. From this post-test average score, the conclusion that can be drawn is the PBL model can improve students' mathematical problem-solving skills in vector analysis courses.

To test the second hypothesis using the test N-gain. The alternative hypothesis tested is "The PBL model is effective in improving students' math skills in vector analysis courses." The test results using Again statistics is 0.44, it can be concluded that "PBL model is effective in improving students' math skills in vector analysis courses" with the medium category.

Based on the results of the first hypothesis test, it can be concluded that the PBL model can improve students’ math problem-solving skills in vector analysis courses, shows that the pre-test averages for PBL model 68.60, and post-test for PBL model 82.26. There is an increase in learning outcomes from before applying the PBL model with after applying the PBL model. For the results of the second hypothesis test, it can be concluded that "PBL model is effective in improving students' math skills in vector analysis courses" with the medium category.

3.2. Research Discussion
The PBL model, the teacher gives students an orientation about the problem and motivates the students to engage in problem-solving activities. Orientation about the problem in question is the teacher gives a problem according to the topic to be discussed, the students are expected to solve the problem in the group. Teachers organize students to research, help students to define and organize learning tasks related to problems, teachers assist independent and group investigations, encourage students to get the right information, carry out experiments, and seek explanations and solutions. To organize the students in question is to form groups and make patterns or maps of thoughts on students looking for solutions to solve problems within the group. Teachers develop and present artifacts and exhibits, help students plan and prepare reports, and help them to communicate to others. Developing and presenting the intended ones is that students should be able to present the results of group discussions in front of other groups. Discussion results are the problem solving of the problems given by teachers within the group. Teachers analyze and evaluate problem-solving processes, help students reflect on their investigations and the processes they use. Based on the stages of learning above it is clear that learning requires more active students. Because in the students' learning is directly involved in the investigation and find the solution of the problem, so in the end, students are helped to become autonomous students who can help themselves, in solving the problems it faces.

The PBL model is a model of group learning, so the PBL model is part of the cooperative learning model. Mandal [3] said that cooperative learning can develop high-level thinking skills, create an active learning environment, improve student performance with less academic ability, and tolerate different learning styles among students.

Some principles in applying the PBL model, namely: (1) all participants listen well to what is delivered by students or other groups; (2) opinions must be based on sound evidence and problem-solving; (3) the discussion process should be in a dialogical setting. So that students are expected after learning PBL model not only have the cognitive ability but also effective or soft skill ability and skill or life skill.
Some of the obstacles encountered in applying the PBL model are: (1) the PBL model is an oral book study, each student or group must have many references on the topic being discussed. So that students have to collect many sources of reference, because at the beginning of the teacher's learning only provide topic material and problems to be solved in the group; (2) high-order thinking that causes students to take time to adjust to the PBL model. The solution given to overcome these problems is to direct and guide students using IT-based technology. Technological advances not only have a negative impact but actually, have a positive impact when used properly and correctly.

4. Conclusion
Based on the results of the results of this study, it can be concluded that the PBL model can improve the ability. The PBL model is effective in improving students' math skills in the medium category. This shows the application of the PBL model to the mathematical abilities of the vector analysis courses. Thus, the PBL model effectively improves the ability.

Based on the results achieved, suggestions can be made as follows. First, on the application of PBL model. Second, the PBL model can be used as an alternative learning model by the lecturer to improve the ability. Third, the use of PBL models is applied to higher learning. Fourth, the PBL model is an oral books learning model so that students can learn independently.

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