The effect of problem-based learning model on students’ geometry achievement by controlling mathematics initial ability

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Abstract. This study aimed to know the difference of geometry learning outcome between students studying with problem-based learning model and students studying with scientific learning approach after controlling mathematics initial ability. The design of this study was non-equivalent control group design. Random sampling technique was used to take the research sample which amounted to 18 students. Technique of collecting data was the tests mathematics initial ability and geometry learning outcome. Data was analysed by using analysis of covariate. The results showed that geometry learning outcomes between students studying with problem-based learning model were higher than that studying with scientific learning approach after controlling mathematics initial ability.

1. Introduction
The importance of mathematics can be seen from the objectives of mathematics courses in primary and secondary education based on the 2006 Curriculum [1], namely: one of the roles of mathematics is to prepare students to be able to face the changing circumstances or challenges in life and in an expanding world. The preparations are made through the exercise of making decisions and conclusions on the basis of thinking logically, rationally, critically, carefully, honestly, efficiently and effectively. In addition, students are expected to be able to use mathematics and mathematical thinking in their daily lives, and in studying the various sciences that emphasizes on the organization of reasoning and the formation of students’ self-confidence and skills in the application of mathematics. The development of present-day needs is mathematics learning that leads to an understanding of the concepts necessary to solve other mathematical and scientific problems. While in the future is needed the formation of reasonable, logic, critical, and careful and objective and open thinking. Development of geometry learning outcome of junior-high-school students is a mandate of mathematics curriculum. The objectives and demands related to the development of geometry learning outcome contained in the curriculum are the subject of mathematics should be given to all learners ranging from elementary school to equip them with the ability thank logically, analytically, systematically, critically, creatively, and solve problem, and generalize it. This is corroborated by several studies that have been done previously by some researchers mentioned that interest has a significant effect on students’ geometry learning outcome. The previous studies show that mathematics initial ability has a significant influence on geometry learning outcome. Not only spatial intelligence factors can affect students’ geometry learning outcome but mathematics initial ability factor also does. Both factors can affect
students’ geometry learning outcomes, yet so far the influence of these two factors on students of class VIII SMP 7 Padang is not known yet.

The purpose of this study is to know the difference of geometry learning outcomes between students studying with problem-based learning model and that studying with scientific learning approach after controlling mathematics initial ability and the influence of mathematics initial ability on students’ learning outcome for the learning material about spatial objects. Therefore, the researcher is interested in conducting a research on "The Effect of Problem-Based Learning Model on Students’ Geometry Achievement by Controlling Mathematics Initial Ability."

1.1. Problem-Based Learning Model

Problem-based learning (PBL) model is a learning model that encourages students to use problem-solving skills. According to Trianto[2], the problem-based learning model is a learning model that is based on many problems that require authentic investigation, that is, investigations that require real solution of real problems. While Suprijono said that, "problem-based learning involves the presentation of authentic and meaningful situations that function as foundation for students’ investment [3]. In addition, problem-based learning is a learning model that shows real problems to students at the beginning of learning. Problems can drive seriousness, challenge, scientific reasoning, and a meaningful and very powerful way of thinking. Matthew B Etherington, in the result of his study, reports on the success of using a problem-based learning (PBL) model as a pedagogical mode of learning open inquiry science within a traditional four-year undergraduate elementary teacher education program [4].

Furthermore, problem-based learning is an effective learning to improve students’ learning outcomes. Rebecca U. Etiubon, revealed that “students taught with a problem based learning approach had a higher mean achievement score than their counterparts taught with an expository approach”[5]. This learning helps students to process information already made in their minds, compile their own knowledge, and share knowledge about the social world and its surroundings. Arends states that problem-based learning is a learning model based on constructivism and accommodates student’s involvement in learning and in contextual problem solving [6]. In this case, students learn about how to build a framework of problems, examine, collect data, and arrange arguments related to problem solving, then solve the problem given. Broadly speaking, problem-based learning is a presentation of meaningful problems that can provide opportunities for the students to investigate and be scientific [7].

1.2. Mathematics Prior Knowledge

Mathematics prior knowledge is mathematics knowledge possessed by students before the learning is started. This knowledge includes school mathematics material as prior knowledge to learn the next mathematics material. [8] explains that the prior knowledge is all competencies at the lower level (sub-tasks) that should have been mastered before students begin a series of specific learning to work on competencies above the initial ability. This statement is in line with Cecco [9], stating that the initial ability is the knowledge and skills possessed by students before they move on to the next level. Therefore, the initial ability becomes an important part of the next cognitive ability. Students who have the required prior knowledge have the possibility to follow and carry out the next learning task. Some experts state the definition of knowledge. One of them is Jonasen and Gabrowski stating that prior knowledge is knowledge, skills, or ability that are brought by students to the learning process[10]. In order to know the level of students’ mathematics prior knowledge, it is needed to do the measurement before the learning begins. This measurement of prior knowledge can be done by using tests both oral and written. The test of mathematics prior knowledge can be used to know weather the students have an appropriate knowledge or not. The result of this test also can be used as prerequisite to follow mathematics learning activities. This is done because of relevance and linkages between mathematics prior knowledge and material that will be learned.
2. Methods
This research was an ex post facto research. Based on its explanation level, this research included descriptive study of quantitative and comparative causal where the research was conducted to collect facts based on symptoms measurement that occur in the respondent self without performing treatments or manipulations on the research variables. Comparative causal research in this study was a cause-and-effect comparison. This comparison was used to determine whether there was influence between independent variables and dependent variable. The research approach used was quantitative approach. The data was tangible number analyzed using statistic to answer the specific research hypothesis and to know whether a variable influenced other variables or not. The population in this study was the students of class VIII SMP 7 Padang and SMP 12 Padang that consisted of 8 classes each. Random sampling technique was used to take the sample of selected research class consisting of 18 students. Data collection techniques used the tests of mathematics initial ability and geometry learning outcome. The content validity test was done by asking opinions from some experts. The item analysis was the students of class VIII SMP 7 Padang and SMP 12 Padang that consisted of 8 classes each. Random sampling technique was used to take the sample of selected research class consisting of 18 students. Data collection techniques used the tests of mathematics initial ability and geometry learning outcome. The content validity test was done by asking opinions from some experts. The item analysis used difficulty level analysis and discrimination index analysis. The reliability test was carried out by using the Chronbach alpha formula. Finally, the data was analysed by using covariate analysis.

3. Result and discussion

3.1. Results
Statistical descriptions of research data included the size of data centralization and distribution. The size of data centralization included average value, mode, and median, while the size of data distribution included range and standard deviation. The variables measured and observed in this study were the students of class VIII SMP 7 Padang and SMP 12 Padang that consisted of 8 classes each. Random sampling technique was used to take the sample of selected research class consisting of 18 students.

| Table 1. Data description of mathematics initial ability’s score and geometry learning outcome. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Visual-Spatial Ability         | X1              | Y1              | X1              | Y1              | X1              | Y1              |
|                                | PBL (A1)        | Scientific (A2) | PBL (A1)        | Scientific (A2) | PBL (A1)        | Scientific (A2) |
| High (B1)                      |                 |                 |                 |                 |                 |                 |
| N                              | 9               | 9.00            | 9               | 9.00            | 18              | 18.00           |
| Mean                           | 69.44           | 84.22           | 51.11           | 65.78           | 60.28           | 75.00           |
| Median                         | 80.00           | 85.00           | 50.00           | 64.00           | 55.00           | 76.00           |
| Mode                           | 85.00           | 74.00           | 45.00           | 62.00           | 55.00           | 62.00           |
| Std. Deviation                 | 24.93           | 5.95            | 11.40           | 5.76            | 21.04           | 11.06           |
| minimum                        | 25              | 74              | 35              | 62              | 25              | 62              |
| maximum                        | 95              | 93              | 70              | 79              | 95              | 93              |
| Low (B2)                       |                 |                 |                 |                 |                 |                 |
| N                              | 9               | 9.00            | 9               | 9               | 18              | 18.00           |
| Mean                           | 69.44           | 81.67           | 51.67           | 77              | 60.56           | 79.33           |
| Median                         | 70.00           | 86.00           | 55              | 79              | 57.50           | 81.00           |
| Mode                           | 60.00           | 71.00           | 55              | 65              | 55.00           | 67.00           |
| Std. Deviation                 | 15.50           | 9.30            | 14.79           | 6.782           | 17.31           | 8.25            |
| minimum                        | 45              | 67              | 35              | 65              | 35              | 65              |
| maximum                        | 90              | 91              | 80              | 84              | 90              | 91              |

| Σ                              |                 |                 |                 |                 |                 |                 |
| N                              | 18              | 18.00           | 18              | 18.00           | 36              | 36              |
| Mean                           | 69.44           | 82.94           | 51.39           | 71.39           | 77.17           | 60.42           |
| Median                         | 77.50           | 85.50           | 52.50           | 69.00           | 79              | 55              |
| Mode                           | 85.00           | 71.00           | 55.00           | 62.00           | 62              | 55              |
| Std. Deviation                 | 20.14           | 7.69            | 12.81           | 8.40            | 9.87            | 1.9             |
| minimum                        | 25              | 67              | 35              | 62              | 62              | 25              |
| maximum                        | 95              | 93              | 80              | 84              | 93              | 95              |
Table 1 shows that mathematics initial ability was labeled as X and geometry learning outcome was labeled as Y. Beside, the data was divided into two groups, namely: 1) students learning with problem-based learning model (A1); and 2) students learning with scientific learning model (A2).

3.1.1. Geometry learning outcome of students studying with problem-based learning model (A1). The data of geometry learning outcome of 18 students studying with problem-based learning showed the highest score of 93 and lowest score of 67. The average score, mode, median, deviation standard, and range were 82.94, 71, 85.50, 7.69 and 26 respectively.

Table 2. Data frequency distribution of geometry learning outcome of students studying with problem-based learning model (A1).

| No | Interval Class | F | Percentage |
|----|----------------|---|------------|
| 1  | 67 – 71        | 3 | 16.67      |
| 2  | 72 – 76        | 1 | 5.56       |
| 3  | 77 – 81        | 2 | 11.11      |
| 4  | 82 – 86        | 4 | 22.22      |
| 5  | 87 – 91        | 7 | 38.89      |
| 6  | 92 – 96        | 1 | 5.56       |
| Sum| 18             |   | 100.00     |

Table 2 shows that the number of students getting geometry learning outcome in interval class 67-71 was 3 students (16.67%), in interval class 72 - 76 was 1 student (5.56%), in interval class 77 - 81 was 2 students (11.11%), in interval class 82 - 86 was 4 students (22.22%), in interval class 87 - 91 was 2 students (11.11%), and in interval class 92 - 96 was 1 student (5.56%). The histogram of the data can be seen in Figure 1.

3.1.2. Geometry learning outcome of students learning with scientific learning approach (A2). The data of geometry learning outcome of 18 students learning with scientific learning approach revealed that the highest score, lowest score, average score, deviation standard, mode, median and range were 84, 62, 71.39, 8.40, 62, 69.00 and 22 respectively. Distribution frequency table of geometry learning outcome of students studying with scientific learning approach can be seen in Table 3.

Table 3 shows that the number of students getting geometry learning outcome in interval class 62 - 65 was 7 students (38.89%), in interval class 66 - 69 was 2 students (11.11%), in interval class 70 - 73 was 1 student (5.56%), in interval class 74 - 77 was 2 students (11.11%), in interval class 78 - 81 was 3 students (16.67%), and in interval class 82 - 85 was 7 students (16.67%). The histogram of distribution frequency can be seen Figure 2.

Figure 1. Histogram of geometry learning outcome of students learning with PBL model (A1).

Figure 2. Histogram of geometry learning outcome of students learning with scientific learning approach (A2).
Table 3. Distribution frequency table of geometry learning outcome of Students studying with scientific learning approach (A2).

| No | Interval Class | F | Percentage |
|----|----------------|---|------------|
| 1  | 62 – 65        | 7 | 38.89      |
| 2  | 66 – 69        | 2 | 11.11      |
| 3  | 70 – 73        | 1 | 5.56       |
| 4  | 74 – 77        | 2 | 11.11      |
| 5  | 78 – 81        | 3 | 16.67      |
| 6  | 82 – 85        | 3 | 16.67      |
|    | Sum            | 18| 100.00     |

Figure 2. Histogram of geometry learning outcome with scientific learning approach (A2).

Hypothesis Testing

Data analyzed using ANCOVA has 6 tests of requirement, namely (1) normal distributed data; (2) the data has homogeneity of variance; (3) the regression resulted between covariate variables and dependent variables is linear; (4) the regression coefficients in each group is homogeneous, (5) covariate variables affect the dependent variable, and (6) the slope of the regression lines of each cell group is homogeneous.

Normality Test of Data

This test was done on 2 data as followos:
1. Overall data of geometry learning outcome of students studying with problem based-learning model (A1)
2. Overall data of geometry learning outcome of students studying with scientific learning approach (A2)

The normality test of sample data was done using the Lillefors test with a significant level $\alpha = 0.05$ in which the test criteria was accept the null hypothesis (Hc), if $L_{count} \leq L_{table}$, but if $L_{count} > L_{table}$, then the null hypothesis (Ho) was rejected. The hypotheses that will be tested by normality test were as follows.

$H_0$: data came from normally distributed populations
$H_1$: data came from populations that were not normally distributed

A summary of normality test results can be seen in Table 4 below.

Table 4 shows that the data of geometry learning outcome tested by Lillefors test gave $L_{count}$ that was smaller that $L_{table}$ with $\alpha=0.05$ and $L_{table} = 0.200$ for $n = 18$. Based on this result, it can be concluded that all geometry learning outcome in this study was sourced from populations that were
normally distributed so that the data normality requirements was fulfilled and further analysis of variance can be done.

**Table 4.** The summary of normality test result.

| No | Group of Data | N  | L count | L table (α=0.05) | Conclusion |
|----|---------------|----|---------|------------------|------------|
| 1  | A1            | 18 | 0.166   | 0.2              | Normal     |
| 2  | A2            | 18 | 0.199   | 0.2              | Normal     |

**Variance Homogeneity Test**

Homogeneity tests were performed on the treatment group data between learning models (A1 and A2). Homogeneity test data was performed with the F test at the significance level $\alpha = 0.05$ where $dk \,(1-\alpha)(k-1)$ with the criteria if the value of $x^2_{\text{count}}$ was smaller that $x^2_{\text{table}}$, then variance from all treatment groups were homogeneous.

**Homogeneity test data between group A1 dan A2**
The calculation result revealed $F_{\text{count}} = 0.13$ and $F_{\text{table}} (\alpha = 0.05)(1:34) = 48.60$. The testing criteria were that $H_0$ was accepted if $F_{\text{count}} \leq F_{\text{table}}$ and vise versa $H_0$ was rejected if $F_{\text{count}} > F_{\text{table}}$. F test for group A1 and A2 showed that $F_{\text{count}}$ was smaller than $F_{\text{table}}$ meaning that $H_0$ was accepted. Thus, it can be concluded that group A1 and A2 had homogeneous variance.

Based on testing of the analysis requirements, namely the normality test and homogeneity test, the analysis of variance requirements have been met so that the next analysis can be done to see the effect of PBL model on geometry learning outcome after controlling mathematics initial ability.

**Regression linearity test**
Regression linearity testing was performed to test whether the covariate regression equation model (X) and the dependent variable (Y) were linear or not. The linearity regression between covariate variable (X) and dependent variable (Y) were performed because inferential statistical testing with ANIKOVA required the linearity of the covariate regression equation model (X) and the dependent variable (Y).

The calculation results of regression linearity of X against Y have been presented in table 5 below. Table 5 shows that $F_{\text{count}}=1.84 < F_{\text{table}} (\alpha = 0.05) = 2.28$, so that it can be concluded that the regression model of the effect of mathematics initial ability on geometry learning outcome was linear.

**Table 5.** ANOVA results of regression Linearity test.

| Sources of Variance | Df  | JK     | RJK    | $F_{\text{count}}$ | $F_{\text{table}} (\alpha=0.05)$ |
|---------------------|-----|--------|--------|-------------------|----------------------------------|
| Total               | 36  | 2175.00|        |                   |                                  |
| Regression (a)      | 1   | 214369 | 214369 |                   |                                  |
| Regression (b)      | 1   | 1179.22| 1179.22| 18.00             | 4.13                             |
| Remainder           | 34  | 2227.78| 65.52  |                   |                                  |
| Compatibility       | 12  | 1116.55| 93.05  | 1.84              | 2.28                             |
| Error               | 22  | 1111.23| 50.51  |                   |                                  |

**Significance Test of Regression Effect**
The significance testing of the regression effect was intended to determine whether the mathematics initial ability as a covariate variable (X) had a significant effect or not on geometry learning outcome (Y). This test was carried out by the significance test of regression coefficient $\gamma = a-bX$ using the F test. The calculation results on the regression line in Table 7 revealed $F_{\text{count}} = 18 < F_{\text{table}} (\alpha = 0.05) (1:34) = 4.13$, so it can be concluded that the covariate variable (mathematics initial ability) had a significant influence on the dependent variable (geometry learning outcome).
Hypothesis Testing
Hypothesis testing was done after the normality and homogeneity testing requirements were fulfilled. Hypothesis testing can be done by testing all of the main effects and interaction effects on geometry learning outcome using covariate analysis (ANKOVA). The main effect of this study was the effect of the use of learning models on geometry learning outcome after controlling mathematics initial ability. To be able to see the significant level of the four hypotheses, then the Tuckey test was proceeded. The calculation results of the covariate analysis (ANKOVA) revealed that geometry learning outcome of students learning with problem-based learning model were higher than that studying with scientific learning approach after controlling mathematics initial ability.

This hypothesis was statistically formulated as follows:

\[ H_0: \mu_{(A_1)} \leq \mu_{(A_2)} \]
\[ H_1: \mu_{(A_1)} > \mu_{(A_2)} \]

\( \mu_{(A_1)} \): geometry learning outcome of students learning with problem-based learning model after controlling mathematics initial ability.
\( \mu_{(A_2)} \): geometry learning outcome of students learning with scientific learning approach after controlling mathematics initial ability.

Based on the result of ANKOVA calculation, the \( F_{\text{count}} \) for the learning model was 14.722, while the \( F_{\text{table}} \) was 4.20 at \( \alpha = 0.05 \). Because \( F_{\text{count}} > F_{\text{table}} \), this meant that the null hypothesis (\( H_0 \)) stating that there were no differences in geometry learning outcome between students learning with problem-based learning model and students learning with a scientific learning approach after controlling mathematics initial ability was rejected and the research hypothesis (\( H_1 \)) was accepted. In the other word, it can be concluded that there were differences in geometry learning outcome between students learning with problem-based learning model and students learning with a scientific learning approach after controlling mathematics initial ability. Additionally, when the Tuckey test was carried out, it revealed that \( q_{\text{count}}=14.94 \) that was greater than \( q_{\text{table}}(\alpha=0.05,n=36,d=3) =2.86 \). From this result, it can be concluded that geometry learning outcome between students learning with problem-based learning model (A1) were higher than that learning with a scientific learning approach (A2) after controlling mathematics initial ability. The result of Tuckey test can be seen in Table 6.

| The compared groups | \( Q_{\text{count}} \) \( (\alpha = 0.05) \) |
|---------------------|----------------------|
| A1 and A2           | 14.94                |
|                     | 2.86                 |

3.2. Discussion
This study basically aimed to determine the effect of learning models on students’ geometry learning outcome after controlling mathematics initial ability. Based on the results of the study, it showed that the learning model had a significant effect on students’ geometry learning outcome after controlling mathematics initial ability. The null hypothesis (\( H_0 \)) was rejected, meaning that there were differences in geometry learning outcome between students studying with the problem-based learning model (A1) and students studying with the scientific learning approach (A2) after controlling mathematics initial ability. This indicated that empirically the problem-based learning model can improve students’ geometry learning outcome compared to the scientific learning approach. The calculation results answered the research hypothesis that the geometry learning outcome of students studying with problem-based learning model (A1) were higher than that studying with scientific learning approach (A2).

Problem-based learning model was an innovative learning model that involves students actively and critically so that they can solve problems through scientific methods and build their own knowledge and develop their thinking abilities in a sustainable manner. Applying problem-based
learning model in the learning process allowed students to get knowledge and skills based on questions that arise from the problems given by the teacher.

Problem-based learning model was a student-centered learning model. This learning model was done by identifying problems, making hypotheses and collecting information related to problems to then be informed to other students. The process of collecting data was done by asking related questions to form scientific attitudes using scientific methods. This meant changing the conventional learning that is presentation of information by the teacher to students as recipients of information into learning that emphasized the information processing by students who actively sought and processed their own information obtained from various sources. This was in accordance with Trianto's opinion stating that the problem-based learning model was a learning model that was based on many problems requiring authentic investigation, which was investigation that required real resolution of real problems.

On the other hand, a study done by Akinoglu dan Tandongan revealed learning that facilitated student activity can influence student achievement. This study was done by comparing learning models that prioritized student activity with scientific learning model. The conclusion from this study was that there was an increase in learning outcomes from the two treatment groups, but in reality the learning outcome of students learning with student activity was higher than that learning with scientific learning approach. Problem-based learning model was a learning that referred to the process of the scientific method so that it made learning more active, independent, logical, and critical. Students were also directed to construct and discover their own knowledge. The teacher no longer dominated the learning activities but only guided and gave students freedom of learning. Students were encouraged to think critically, take initiative, formulate hypotheses in order to obtain solutions of the problems provided so they were motivated in learning.

Problem-based learning (PBL) model can be said to be more effective than learning oriented towards achieving goals. Regarding this, Arends suggested that “PBL helps students develop their thinking and problem solving skills, learn authentic adult roles and become independent autonomous learners”, meaning that by applying problem-based learning thinking skills and problem solving skill can be developed. Based on these findings, it was evident that problem-based learning model provided students a freedom of learning compared to scientific learning modes. This learning model fostered student’s motivation and was more meaningful than direct learning model. The tendency that emerged from problem-based learning model fostered student’s curiosity, the activeness and creativity as well as critical thinking so that learning became effective and efficient.

On the other hand, scientific learning model was a learning when the teacher explained about facts and concepts which were then followed by exercises and feedback to students in order to help them gain the knowledge and skills needed in learning. Besides, the scientific learning approach was a learning model that referred to a model that consisted of teacher's explanation of new concepts and skills to students which was then continued by testing students’ understanding under the guidance of the teacher. Scientific learning approach was a model designed to support the learning process which was delivered gradually and in a structured way. In the process students learned by observing, remembering, and concluding from the learning material informed by the teacher. Students certainly were required to pay attention to the learning material that must be learned, possessed everything that has been delivered by the teacher to then memorized and utilized it back into the tasks given. The process of transferring information from the teacher to students directly was by organizing lesson time so that learning objectives were achieved as clearly, effectively and efficiently as possible. Information presentation was more procedural and declarative in a step-by-step pattern. This was explicit because the regularity of the learning material and the clarity of the steps taken by the teacher did not confuse students in learning the material that has been delivered.

Scientific learning approach emphasized the teacher to provide regular and sequential explanations which were then stored in students’ memories as new knowledge. The learning material that was delivered in a structured manner also gave benefit to students because the difficulties caused in completing assignments will be able to increase students’ persistence so that the learning became more
meaningful. This was in line with the opinion of M. Hosnan saying that scientific learning was a learning process designed in such a way that students actively constructed concepts, laws or principles through the stages of observing (to identify or find problems), formulated problems, proposed or formulated hypotheses, collected data with various techniques, analyzed data, drew conclusions and communicated the concepts, laws or principles found. In scientific learning students were only required to understand and memorize information or learning material delivered by the teacher, giving rise to the assumption that learning material in mathematics contained standard subject matter that cannot change with certain truths, which made students tend to be passive and ineffective.

This proved that the application of different learning models would bring different results. Geometry learning outcome of students studying with problem-based learning model would be different from that studying with direct learning model. This showed that the application of two learning models would produce different learning outcomes. However, the application of appropriate learning model would be able to help students achieve maximum learning outcomes.

4. Conclusion
Based on the results and discussion that has been stated previously, it can be drawn conclusion that geometry learning outcome of students studying with problem-based learning was higher than that studying with scientific learning approach after controlling mathematics initial ability that was shown by the result of \( F_{\text{count}}^{14,722} > F_{\text{table}}^{4.20} \).

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