The Influence of Project-based Learning (PjBL) and Learning Style on Mathematics Communication Skills of Junior High School Students

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Abstract. Teachers have an important role to improve the mathematical communication skills of students as one of the skills to implement mathematical learning. The purpose of this research is to find out how the Project-based learning (PJBL) affects students' communication skills, to know the influence of learning styles on student communication skills, and to know the learning model interactions between Project-based learning (PJBL) and learning style to the communication skills of junior high school students. The method used is the quasi-experimental method. The study employed the two-way analysis techniques variance (ANOVA) with un-equivalent cells. Based on the results of the hypothesis testing, it can be concluded that (1) there is an influence of Project-based Learning (PJBL) which produces better mathematical communication skills than students in conventional learning, (2) there is a difference in the influence between auditory learning style, visual, and kinesthetic toward the students' mathematical communication skills. Students with auditory and visual learning styles are better on mathematical communication skills, and (3) there is no interaction between learning models and learning styles toward students' mathematical communication skills.

1. Introduction

Learning mathematics has quite a lot of problems in its implementation. One of the important problems in mathematics learning today is the importance of developing mathematical communication skills as one of the purposes of learning mathematics and become one of the competency standards of graduates in the field of Mathematics [1]. Mathematical communication skills aim to allow students to use logic on properties and patterns, create mathematical manipulations to generalize, explain ideas, compose mathematical evidence and statements, and communicate ideas into tables, media, symbols, or diagrams to describe problems [2]. However, there are still issues of students' low communication skills. Students have difficulty in transforming the description into mathematical models and are less capable of writing the answers. It can be said that the students' mathematical communication skill is still low [3].

The efforts that can be done in enhancing the students' mathematical communication skills are by using the right learning model. One of the learning models that can be used to address the problem is Project-based learning (PJBL) [3]. The PJBL model is a model that requires students to be active during the process and requires teachers to lead the process, provide feedback to students and assess
their performances, recognize the tendency of passive students, and activate the project-based activities [4, 5]. The learning process through PjBL allows teachers to learn from students and learn with students. Learning through PjBL can be used as a learning model for developing students' skills in planning, communicating, resolving problems, and making decisions. In addition to learning methods, Learning success is also determined by one's learning style [6]. Learning style is believed to improve the achievement or outcome of one's learning [7]. If each individual can manage the learning style, then learning will be more effective and efficient so that the achievement of learning is higher.

Several studies on the Project-based learning have been conducted in much educational research [5, 8–12], research in measuring the mathematical communication skills have been conducted by some previous researchers [3, 13–24] or research by looking at student learning styles [25,26]. However, research in terms of measuring the students' mathematical communication skills that are seen from the learning style as well as using the Project-based Learning model has never been done. Based on previous research, researchers are interested in researching with the novelty of seeing the influence of Project-based learning and learning style on students' mathematical communication skills. Thus, the purpose of this study is to determine the influence of Project-based learning (PjBL) on students' communication skills, to know the influence of learning style on students' communication skills, and to know the interaction between PjBL and learning styles toward the communication skills of junior high school students.

2. Research methods
The type of research used in this study is quasi-experimental research. The research design is described in table 1.

| Learning Model (X<sub>i</sub>) | Communication (Y) |
|-------------------------------|-------------------|
| Project-based Learning (PjBL) (X<sub>1</sub>) | X<sub>1</sub>Y |
| Conventional Learning (X<sub>2</sub>) | X<sub>2</sub>Y |

Description:
X<sub>i</sub>: Learning Model
Y: Communication Skills
X<sub>1</sub>: Project-based learning(PJBL) and learning style
X<sub>2</sub>: Conventional Learning
X<sub>1</sub>Y: Project-based learning (PjBL) on communication skills
X<sub>2</sub>Y: Conventional learning Model on communication skills

The instrument used was a learning style questionnaire and a description test to know the student's mathematical communication skills. The test instrument consisted of the validity test, reliability, discriminating index, and difficulty level. The data analysis technique used in this study was the two-way analysis technique of variance (ANOVA) of unequal cells. Before testing the hypothesis, the prerequisite tests were first conducted. The prerequisite test was used to test the normality by using Lilliefors and homogeneity by using the Bartlett test.

Assumptions to test the normality with the equivalent significance of (α): 0.05 are:
H<sub>0</sub>: Data with normal distribution
H<sub>1</sub>: Data does not normally distributed
Test criteria: If the data is normally distributed, L<sub>observed</sub> ≤ L<sub>critical</sub>, H<sub>0</sub> is accepted
Assumptions for the homogeneity test are:
H<sub>0</sub>: Homogeneous Data
H<sub>1</sub>: Data is not homogeneous.
Test criteria: If the value is $\chi^2_{\text{observed}} \leq \chi^2_{\text{critical}}$, then $H_0$ is accepted so that the data is homogeneous.

3. Results and discussion
This research was conducted to 60 junior high school students consisted of 30 students taught by using a Project-based learning (PJBL) learning model and 30 students taught by using a direct learning model. The subject matter in this study is the line and sequence material.

3.1 Analysis of Instrument test
The instruments in this study include students' learning style questionnaire and the mathematical communication skills test. The study results and analysis of the instrument test data are described as follows.

1) Validity Analysis of Tests
Contents and construct validity were used to validate the instruments. The instruments were validated by three validators. The results of the three validators show that 10 items of mathematical communication skills test were worth using for testing.

2) Item Validity Test
The product-moment correlational formula of the Corrected Item Formula-Total correlation coefficient was used to validate the items. The question was categorized as valid if $(r_{x(y+)}> 0.444)$ whereas the question was categorized as invalid if $(r_{x(y+)}<0,444)$. The question item number 4, 8, and 9 were categorized as invalid because $(r_{x(y+)}<0,444)$ and the question item number 1, 2, 3, 5, 6, 7, and 10 were categorized as valid because $(r_{x(y+)} \geq 0.444)$. Item with an invalid category cannot be used because it is not functioning properly as a measuring instrument.

3) Reliability Test
The reliability test calculation result with the Cronbach Alpha formula obtained $r_{11}$ value = 0.705. $r_{11}$ value gained compared to $r_{\text{critical}} = 0.444$. Based on the calculation results, it can be concluded that $R_{11} \geq r_{\text{critical}}$, so that these instruments were categorized reliable and consistent in measuring samples and were worth using for the mathematical communication skills test.

a. Item Difficulty Test
Difficulty level test is a test used to measure the difficulty level of problems and categorize them into easy, moderate, or difficult category. Of the 10 tested items, there was 1 question with the difficulty level of $\leq 0.30$. 8 items were categorized as $0.30 \leq 0.70$, namely items number 1, 2, 3, 4, 5, 8, 9, 10 and items that were categorized as moderate $(No.7) \geq 0.70$.

b. Discriminating Index Test
This test is used to see the classification of students' work (good, moderate, and poor). Based on the results obtained, 3 items were categorized as good $(DI > 0.40$ and $\leq 0.70$) which were questions number 1, 2 and 5. There were 5 items categorized as moderate $(DI > 0.20$ and $\leq 0.40$) which were items number 3, 6, 7, 9 and 10. Two questions were considered as poor (number 4 and 8). The items categorized as poor cannot be used.

c. Conclusion of Tests
Based on the results of the analysis of all the test items, the conclusion can be seen in table 2.

| NO | Validity | Difficulty level | Discrimination Index | Reliability | Conclusion |
|----|----------|------------------|----------------------|-------------|------------|
| 1  | Valid    | Medium           | Good                 |             | Taken      |
| 2  | Valid    | Medium           | Good                 | RELIABLE    | Taken      |
| 3  | Valid    | Medium           | Moderate             |             | Not taken  |
The result of the test analysis on table 2 shows that out of the 10 questions, 7 valid questions can be used. However, two items within a poor category cannot be used. Based on the discussion, it can be concluded that only 5 items met the expected test criteria (Number 1, 2, 5, 6 and 7). The five items were used for the posttest applied in the experimental class and the control class.

3.2 Description of Observation Data
Data on student learning styles were derived from the learning style questionnaire given to students. Furthermore, the data were grouped into three categories: auditory, visual and kinesthetic. The data collected can be seen in table 3:

| Learning Model          | Learning Style | Auditory | Visual | Kinesthetic | Total |
|-------------------------|----------------|----------|--------|-------------|-------|
| Project-based Learning (PjBL) | 20            | 7        | 3      | 30          |
| Conventional            | 20            | 4        | 6      | 30          |
| Total                   | 40            | 11       | 9      | 60          |

According to table 3, the numbers of students in both classes were the same. In the experimental class, there were 20 students with an auditory learning style, 7 students with a visual learning style, and 3 students with a kinesthetic learning style. In the control class, there were 20 students with an auditory learning style, 4 students with a visual learning style, and 6 students with a kinesthetic learning style.

3.3 Data Analysis of Research Results
1) Data Description of the Posttest on Mathematics Communication Skills
The final Test (posttest) was carried out at the end of the learning process to see the influence of the Project-based learning (PJBL) model on mathematical communication skills as a treatment in the experimental class and a conventional approach as the treatment in the control class. Data Description of posttest results can be seen in table 4:

| Group          | X_max | X_min | Central theoretical size | Group size | Variances |
|----------------|-------|-------|--------------------------|------------|-----------|
|                |       |       | X | M₀ | Mₑ | R  | Sd  |
| Experimental   | 100   | 41,25 | 76,87 | 93,50 | 75,00 | 58,75 | 18,18 |
| Control        | 81,25 | 12,5  | 44,29 | 27,50 | 42,50 | 68,75 | 18,47 |

Based on table 4, it indicated that the experiment class obtained the highest score of 100 and the lowest score of 41.25 with the average score of (X) 76.87, mode (M₀) 93.5, median (Mₑ) 75, range of 58.75, and standard deviation of 18.18. The control class obtained a maximum score of 81.25 and a...
minimum score of 41.25 with the average score of (\(\bar{X}\)) 44.29, mode (\(m_0\)) 27.5, median (\(M_e\)) 42.5, range of 68.75, and standard deviation of 18.47. It can be concluded that the experimental class results are greater than the control class.

2) Prerequisites Test
   a. Normality Test
   The normality test was performed to determine whether the sample was normally distributed or not by using the Lilliefors test. The normality test result is presented in Table 5.

   **Table 5. Test Normality Test Result**

   | Group       | \(L_{\text{observed}}\) | \(L_{\text{critical}}\) | Test results         |
   |-------------|--------------------------|--------------------------|----------------------|
   | Experimental| 0.102                    | 0.159                    | \(H_0\) is accepted  |
   | Control     | 0.072                    | 0.159                    | \(H_0\) is accepted  |
   | Auditory    | 0.072                    | 0.139                    | \(H_0\) is accepted  |
   | Visual      | 0.198                    | 0.251                    | \(H_0\) is accepted  |
   | Kinesthetic | 0.124                    | 0.274                    | \(H_0\) is accepted  |

   According to table 5, it appears that in the experiment class' \(L_{\text{observed}} = 0.102\) and the control class' \(L_{\text{observed}} = 0.072\). The auditory learning style's \(L_{\text{observed}} = 0.072\), the visual learning style's \(L_{\text{observed}} = 0.198\), and kinesthetic learning style's \(L_{\text{observed}} = 0.124\). It appears that the \(L_{\text{observed}} \leq L_{\text{critical}}\) which means \(H_0\) is accepted. So, it is concluded that the sample was normally distributed.

   b. Homogeneity Test
   A homogeneity test is a test used to determine whether the variance of a population is the same or not. The test used was the Bartlet test. The results of the homogeneity test with a significance of \((\alpha) = 5\%\) can be seen in the following table.

   **Table 6. The Summary of Homogeneity Test**

   | Group           | \(\chi^2_{\text{observed}}\) | \(\chi^2_{\text{critical}}\) | Test results   |
   |-----------------|-------------------------------|-------------------------------|----------------|
   | \(A_1\) and \(A_2\) | 0.007                         | 3.481                         | Homogeneous    |
   | \(B_1, B_2, B_3\) | 0.582                         | 5.591                         | Homogeneous    |

   According to table 6, it appears that the value of \(\chi^2_{\text{observed}}\) for each group is less than \(\chi^2_{\text{critical}}\), this means that the data in each group have the same variances.

3) Hypothetical Test
   The hypothetical test used was a parametric test of two-way variance analysis (ANOVA) with unequal cells because the known data comes from the normally distributed population and has the same population variances.

   **Table 7. The Results of Two-Way Variance Analysis (ANOVA) with Unequal Cells**

   | Class   | LEARNING STYLE | Auditory | Visual | Kinesthetics |
   |---------|----------------|----------|--------|-------------|
   |         | N              | 20       | 7      | 3           |
   | N       | \(\sum x\)    | 1544.25  | 593.25 | 168.75      |
   |         | \(\bar{x}\)   | 77.2125  | 84.75  | 56.25       |
   |         | \(\sum x^2\)  | 124564.8125 | 52233.0625 | 10082.8125 |
Based on data analysis calculations, it can be inferred:

a. \( F_a = 36.219 \) with a significance of 5% and \( F_{critical} = 4.0195 \), so that \( F_a > F_{critical} \). It indicates that \( H_0\) is rejected which means that there is an influence of the Project-based learning (PJBL) model.

b. \( F_b = 4100.73 \) with a significance of 5% and \( F_{critical} = 3.168 \), so that \( F_b > F_{critical} \). It indicates that \( H_0b \) is rejected which means that there is an influence of auditory, visual and kinesthetic learning styles on students' mathematical communication skills.

c. \( F_{ab} = 405.710 \) with a significance of 5% and \( F_{critical} = 3.168 \) so that \( F_{ab} < F_{table} \). It indicates that \( H_{0ab} \) is accepted which means that there is no interaction between learning models and learning styles on mathematical communication skills.

3.4 Double Compensating Test

Based on the calculation results of ANAVA, \( H_{0A} \) is rejected. However, there is a learning model that only has two criteria. To ensure that the null hypothesis is rejected, this test was performed. The summary calculation is presented in table 9:

| Learning Model | Learning Style | Marginal Average |
|----------------|----------------|------------------|
| PjBL           | Auditory       | 77,212           |
|                | Visual         | 8,750            |
|                | Kinesthetic    | 56,25            |
| Conventional   | Auditory       | 50,250           |
|                | Visual         | 42,12            |
|                | Kinesthetic    | 25,83            |
| Average        | Auditory       | 63,731           |
|                | Visual         | 63,46            |
|                | Kinesthetic    | 41,04            |

Based on table 9, the marginal rate on the Project-based learning (PjBL) learning model is greater than the conventional learning model, thus, it can be concluded that the Project-based Learning (PjBL) is better than conventional learning model.

Based on the calculation results, \( H_{0B} \) is rejected. The students' learning styles are categorized into three categories i.e. auditory, visual and kinesthetic, so it is necessary to do the Inter-column Combination Test using the Scheffe method. The results can be seen in the following table.
Table 10. Double Inter-column Combination Test

| No | Interaction   | $F_{observed}$ | $F_{critical}$ | Conclusion       |
|----|---------------|----------------|----------------|------------------|
| 1  | $\mu_1$ vs $\mu_2$ | 0.262          | 3.168          | $H_0$ is accepted |
| 2  | $\mu_1$ vs $\mu_3$ | 22.69         | 3.168          | $H_0$ is rejected |
| 3  | $\mu_2$ vs $\mu_3$ | 22.47         | 3.168          | $H_0$ is rejected |

The Scheffer test results in table 10 can be described as follows:

1) The interaction of $\mu_1$ vs $\mu_2$ obtained the result that $F_{observed} = 0.262$ and $F_{critical} = 3.168$, thus $H_0$ is accepted. This means that the mathematical communication skills of students with an auditory learning style are equally good for students with visual learning styles.

2) The interaction between $\mu_1$ vs $\mu_3$ obtained the result that $F_{observed} = 22.69$ and $F_{critical} = 3.168$, thus $H_0$ is rejected. This means that the mathematical communication skills of students with auditory styles are better than students with kinesthetic learning styles.

3) The interaction between $\mu_2$ vs $\mu_3$ obtained the result that $F_{observed} = 22.47$ and $F_{critical} >= 3.168$, thus $H_0$ is rejected. This means that the mathematical communication skills of students with visual learning styles are better than the students with kinesthetic learning styles.

The Project-based learning (PjBL) model is an instructional model that allows teachers to manage classroom learning by engaging project work involving complex tasks based on problems. These problems are given to students as steps in collecting and integrating new knowledge based on their experience in real-life activities and demanding students to design and conduct research activities, solving problems, making decisions, allowing students to work independently or in groups. The final result of the project work is a product which is a written report, presentation, or recommendation. Project assignment assessments are carried out from the planning process, project assignment, to project final result.

The PjBL model requires the students to be active and can independently work on assignments and power the students’ creativity. One of the advantages of the PjBL learning model is that students can develop self-reliance beyond teacher supervision so that the students can develop their independence. Learning activities with the PjBL model keep students busy with existing projects so that they can enjoy every learning activity, although not all like it, but the impact of the PjBL learning model can help to solve students' doubts in mathematics learning and can foster a spirit of learning. The project-based learning model not only increases the enthusiasm, intensity, and skills in participating but also assist them in increasing understanding of the material [12]. The PjBL implementation steps consist of (1) project determination (2) project completion planning (3) schedule drafting (4) Monitoring (5) testing results and presentations (6) Process evaluation and project results [5].

The first phase is specifying fundamental or essential questions. Students are expected to build their knowledge based on the learning experience within their groups. The second stage is designing project planning. After they can formulate fundamental questions for their projects, the project will be designed. Students work in groups to make a plan on how their project is implemented. The third stage is to create a schedule. Students must make scheduling that keeps the project well done using an effective time. The fourth stage is monitoring the progress of the project. The progress of the project will be monitored by the teacher and provide additional assistance if necessary. The fifth stage is to test the process and learning outcomes through presentations. The last stage is evaluation, the teacher facilitates the students to think and recall the best things that they had been able to make while working on the project. For further evaluation, the teacher can employ tests.

The implementation of the Project-based learning(PJBL) model resulting in better mathematical communication skills than the application of conventional learning or direct learning. The results of this study are also in line with previous research by Ratna Ambarwati [3] and also in line with Purnomo’s research on students' Mathematics learning performance [27]. Some previous studies examine the mathematical communication skills, one of which is research by Supriyadi who stated that there is an influence between mathematical communication skills to learning outcomes [22].
previous research studied by Jagantara states that learning styles have no interaction with Project-based learning (PJBL) [28].

4. Conclusions and suggestions
Based on the results of the research and discussion, it can be concluded that (1) there is an influence of Project-based Learning (PJBL) model on students’ mathematical communication skills, (2) there are differences in the influence between auditory, visual, and kinesthetic learning style on mathematical communication skills. Students with auditory and visual learning styles are better on mathematical communication skills. (3) There is no interaction between learning models and learning styles on mathematical communication skills. Based on the conclusion of this research, it is expected for further researchers to examine the other skills in mathematics learning by using the PJBL learning model.

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