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THE INFLUENCE OF PROJECT BASED LEARNING (PJBL) ON MATHEMATICAL COMMUNICATION SKILLS IN RELATION TO COGNITIVE STYLES

Nadia Amanda Sari[1,a], Irma Fitri[2,b]
[1,2] Pendidikan Matematika, UIN Sultan Syarf Kasim Riau, Pekanbaru, Indonesia
Jl. H.R. Soebrantas No. 155 KM. 15 Tuah Madani Panam, Pekanbaru, Riau, Indonesia
e-mail: [a]Sarinadiaamanda@gmail.com, [b]Irmafitri@uin-suska.ac.id

Abstract

This study aims to examine the influence of the Project-Based Learning (PjBL) model compared to the Discovery Learning model on mathematical communication skills, considering students cognitive styles. This research adopts a quantitative approach with a factorial experimental design. The population consists of students from classes VII F, VII G, VII H, and VII I at SMP Negeri 1 Pangkalan Kerinci. The sample was selected using cluster random sampling, with class VII H assigned as the experimental group (PjBL) and class VII I as the control group (Discovery Learning). The total sample size was 67 students. Data were collected using mathematical communication skills tests, the Group Embedded Figures Test (GEFT) for cognitive style assessment, and documentation. Data analysis techniques included normality tests, homogeneity tests, and two-way ANOVA. The results of this study are (1) There is a difference in the ability of students who learn using the Project Based Learning model to obtain better mathematical communication skills than Discovery Learning students. (2) There is a difference between students with a field independent cognitive style obtaining better mathematical communication skills than students with a field dependent cognitive style. (3) There is no interaction effect between Project Based Learning and cognitive style on mathematical communication skills.

Keywords: *Cognitive Style; Mathematical Communication; (PjBL) Project Based Learning.*

1. INTRODUCTION

Communication that occurs in the classroom involving mathematical concepts—such as design, formulas, or problem-solving—is referred to as mathematical communication [1]. Mathematical communication skills help students understand

mathematical notations and terms so they can communicate ideas accurately and precisel [2]. In mathematics education, essential competencies that students must master, as outlined by the National Council of Teachers of Mathematics (NCTM), include mathematical communication [3]. According to the Indonesian Minister of Education and Culture Regulation No. 21 of 2016 on content standards for primary and secondary education, students must possess the ability to communicate mathematical ideas clearly [4]. This indicates the significant importance of mathematical communication skills for learners. However, students mathematical communication abilities remain relatively low [5]–[7]. This is because they have not yet mastered key indicators of mathematical communication, such as translating problems into tables or graphs, describing problems effectively, interpreting questions presented in tables or graphs, and correctly translating mathematical symbols [8]–[13]. Indicators of Mathematical Communication Ability Writing (Written Text), using their own words to explain ideas or modeling problems in written form; Drawing (Visual Representation), illustrating real-world objects or diagrams to convey mathematical ideas; Mathematical Expression, expressing mathematical concepts by translating everyday situations into mathematical language and symbols [14].

Mathematical communication is highly important in mathematics learning, making it necessary to implement teaching models that can enhance this ability. The Project-Based Learning (PjBL) model is one such approach believed to improve mathematical communication because it is process-oriented, problem-focused, and centered on learning units. PjBL learning units integrate concepts from various components, including knowledge, disciplines, and experiences [15]. Previous research indicates that the PjBL model can help students improve their mathematical communication skills [16]–[18]. The Discovery Learning model is a teaching approach that encourages students to actively explore concepts [19]

Students mathematical communication abilities are aligned with their capacity to process information, which is referred to as cognitive style. Differences in how individuals process information based on their experiences are called cognitive styles [20]. Cognitive style refers to a person's habitual way of processing information. The most commonly used cognitive styles are Field Dependent (FD), which is influenced by the environment, and Field Independent (FI), which is not influenced by the environment. Students cognitive styles affect their communication abilities [21]–[26]. Indicators of Field Independence include individualism, self-determined strategies, intrinsic motivation, preference for independent work, structured learning, and self-reliance [27]. Indicators of Field Dependence include sensitivity to the surrounding environment, susceptibility to stress, preference for group work, externally set goals, external motivation, and less structured learning [27].

Based on research by Jaki Maulana Syah and Deddy Sofyan titled "Mathematical Communication Skills of Junior High School Students in Kampung Paledang Suci Kaler on Quadrilateral and Triangle Topics," the findings show that students have not yet mastered the indicators of mathematical communication, resulting in low mathematical communication skills [28]. Another study by Dewi Yuliani and Yeyen Vioskha, titled "Mathematical Communication Skills in Relation to Learning Interest of Students at SMP Negeri 32 Pekanbaru," found that students struggled to communicate problems in table or graph form, illustrate problems, or interpret questions presented in tables or graphs, leading to low mathematical communication skills [13]. Research by Nur Asuro and Irma Fitri, titled "Analysis of Mathematical Communication Skills in Relation to Self-Concept Among High School Students," concluded that, overall, the mathematical communication skills of students at SMA Negeri 1 Kampar fall into the moderate category [29].

The novelty of this study lies in its use of quadrilateral material for seventh-grade students. Additionally, this research incorporates three variables: PjBL, Mathematical Communication, and Cognitive Style.

The objectives of this research are to determine: (1) whether there are differences in mathematical communication skills between students learning with the Project-Based Learning (PjBL) model and students learning with Discovery Learning. (2) whether there are differences in mathematical communication skills between students with field-dependent cognitive styles and those with field-independent cognitive styles. (3) whether there is an interaction effect between the PjBL learning model and cognitive styles on mathematical communication skills.

2. RESEARCH METHODOLOGY

This research is an experimental study using a factorial design. The population of this study consists of classes VII F, VII G, VII H, and VII I at SMP Negeri 1 Pangkalan Kerinci for the 2023/2024 academic year. The sample was determined through cluster random sampling at SMP Negeri 1 Pangkalan Kerinci, and two classes were randomly selected as the experimental and control groups. The class taught using the Project-Based Learning (PjBL) model served as the experimental group, while the class taught using the Discovery Learning model served as the control group. The total sample in this study was 67 students, consisting of 33 students in the experimental group and 34 students in the control group.

The steps of the PjBL learning model include: formulating fundamental questions, designing the project, creating a schedule, monitoring project progress, assessing outcomes, and evaluating experiences [30]. Meanwhile, the steps of the Discovery Learning model consist of: stimulation, problem identification, data collection, data processing, verification, and drawing conclusions [31].

This study has an independent variable (PjBL), a dependent variable (mathematical communication skills), and a moderator variable (cognitive style). Data collection was conducted using tests, observation, and documentation. Tests were used to gather data on mathematical communication skills and cognitive style. The validity of the instruments was tested beforehand. The mathematical communication test underwent item validity testing, item reliability testing, discrimination analysis, and difficulty index analysis. Meanwhile, the validity of the cognitive style test instrument was assessed using the Group Embedded Figures Test (GEFT). The GEFT is a non-verbal test, and its psychometric properties have been cross-culturally validated. Based on the Spearman-Brown formula, the reliability of the GEFT was reported as 0.82 for male students (N = 80) and female students (N = 97). According to Fyle,, as cited by Puspananda, the validity, reliability, and internal consistency of the GEFT are supported by several research findings, including those conducted by Witkin [32].

The documentation method was used to collect photos of each learning activity. The observation method was used to monitor whether the learning process followed the PjBL steps. The prerequisite tests for this study included a normality test using the Chi-Square test and a homogeneity test using Bartlett's test, followed by hypothesis testing using two-way ANOVA.

Generally, the research procedure was divided into three stages: preparation, implementation, and completion.

A. Preparation Stage

At this stage, the following steps were carried out:

1. Identifying the research problem
2. Proposing the research title
3. Drafting the research proposal
4. Developing the teaching module for the study

5. Conducting a proposal seminar
6. Revising the proposal based on seminar feedback
7. Obtaining research permits
8. Preparing learning materials, including the teaching module and summative test questions
9. Preparing data collection instrumens, consisting of:
   a. The test grid and trial questions for the pretest and posttest of students mathematical communication skills
   b. Answer keys for the pretest and posttest trial questions
   c. The GEFT for students cognitive styles
10. Testing the research instruments on a trial class
11. Analyzing the results of the pretest and posttest trials on mathematical communication skills
12. Administeringing the pretest to classes VII F, VI G, VII H, and VII I.
13. Analyzing pretest data from each class for normality, homogeneity, and mean quality
14. Randomly selecting the sample from the population classes VII F, VII G, VII H, and VII I.

B. Implementation Stage

This stage involved the following activities:

1. Administering the test GEFT to assess the cognitive styles of students in the experimental and control groups, then processing and analyzing the GEFT results
2. Conducting PjBL-based learning in the experimental group and discovery learning in the control group
3. Observing the experimental class
4. Distributing the posttest on mathematical communication skills to both groups

C. Completion Stage

At this stage, the following activities were conducted:

1. Collecting quantitative and qualitative data from the control and experimental groups

2. Processing and analyzing quantitative data from the posttest
3. Processing and analyzing qualitative data from observation sheets and the GEFT
4. Consulting the data analysis results with the supervising lecturer
5. Drawing research conclusions based on the formulated hypotheses
6. Compiling the research report
7. Revising the report after guidance sessions with the supervising lecturer

3. RESULTS AND DISCUSSION

Before obtaining the research results, the researcher conducted a series of processes to test the hypotheses. The researcher administered a pretest and posttest with six questions on mathematical communication skills to 26 students from SMP Negeri 5 Pangkalan Kerinci. During the trial of the test questions, a validity test was conducted, yielding valid results. Subsequently, a reliability test resulted in fairly good reliability. In the difficulty analysis, one question was classified as easy, and five questions were considered medium/difficult. Then, in the differentiating power test, three questions were rated as poor, and three questions were rated as adequate. After the trial, a pretest was administered to classes VII F, VII G, VII H, and VII I of SMP Negeri 1 Pangkalan Kerinci. Table 1 summarizes the results of the trial questions.

Table 1 Recapitulation of Trial Question Results

No. Question	Validity	Reliability	Difficulty Level	Differentiating Power	Remarks
1	3,0530	0,599488907	0,826923078	0,115	Used
2	2,5139		0,673076923	0,0775	Used
3	5,7314		0,692307693	0,23	Used

4	2,7426	0,64423077	0,0975	Used
5	2,6512	0,586538463	0,2125	Used
6	5,3329	0,634615385	0,27	Used

After conducting the pretest, the researcher performed a normality test, which showed a normal distribution. Then, a homogeneity test was conducted, and the results indicated that the variances were homogeneous. Afterward, a one-way ANOVA test revealed no significant difference in mathematical communication skills. Therefore, the samples could be selected randomly using a lottery system to determine the experimental class and the control class. The experimental class obtained was Class VII H, while the control class was Class VII I. Before starting the learning process, the researcher administered the GEFT (Group Embedded Figures Test) to both the experimental and control classes to determine the cognitive styles of each student. In the experimental class, there were 14 students with a Field-Independent (FI) cognitive style and 19 students with a Field-Dependent (FD) cognitive style. Meanwhile, in the control class, there were 12 students with an FI cognitive style and 22 students with an FD cognitive style. Table 2 shows the results of the pretest normality test. Table 3 presents the results of the pretest homogeneity test. Table 4 displays the results of the One-Way ANOVA test.

Table 2 Results of the Pretest Normality Test

Class	$X^2_{calculated}$	X^2_{table}	Criteria
VII F	4,0249	11,07	Normally Distributed
VII G	7,996		Normally Distributed
VII H	8,00745		Normally Distributed
VII I	3,3642		Normally Distributed

Table 3 Results of the Pretest Homogeneity Test

$X^2_{calculated}$	X^2_{table}	Conclusion

3,1359951	7,815	Homogeneous

Tabel 4 Results of the One-Way ANOVA Test

$f_{calculated}$	f_{table}	Remarks
1,601	2,69	No differences in mathematical communication abilities

The research was conducted over five sessions, excluding the pretest and posttest. The experimental class used the Project-Based Learning (PjBL) model, while the control class used the Discovery Learning model. At the beginning of the sessions, students were still unfamiliar with the PjBL learning model. The PjBL steps began with students observing the fundamental questions in the project worksheet. The researcher guided the students to identify the characteristics of lines and angle sizes. Next, the researcher explained that the tasks should be completed sequentially, up to the reflection stage.

Afterward, students discussed with their respective groups about the project they would work on. They discussed the maximum planned time, the aspects to be reported, the tools and materials needed, and the steps required to complete the project. The researcher then agreed on a 40-minute time limit for completing the project. Subsequently, the researcher asked students to discuss among their group members to finalize the project. The researcher moved around the classroom to monitor the students performance and provided explanations if students did not understand the assigned tasks.

After completing the project worksheet, the researcher selected one group to present their work. The researcher then gave other students the opportunity to respond to the presenting group. Following this, the researcher summarized the results of the students project worksheets.

Next, the researcher guided the students in discussing any difficulties or obstacles they encountered during the project worksheet discussion, as well as their feelings while completing the project. At the end of the session, the researcher gave individual exercises to reinforce the students understanding of the material. Since this was a new learning model, students were still awkward and hesitant during discussions and presentations.

By the second session, students began to adapt, and each subsequent session showed improvement. Students were highly enthusiastic about learning with the PjBL model because it helped them become more active and express their opinions without fear of being wrong.

The implementation of the PjBL model concluded with a posttest. The posttest was conducted to determine whether there was a difference in mathematical communication skills between students who learned using the PjBL model and those who used Discovery Learning. It also assessed whether there was a difference in mathematical communication skills between students with field-independent and field-dependent cognitive styles, as well as whether there was an interaction effect between PjBL and cognitive style on students mathematical communication skills.

After the posttest, the researcher analyzed the results using a normality test (normally distributed), a homogeneity test (homogeneous), and a two-way ANOVA.

Following the normality and homogeneity tests, a two-way ANOVA was performed. Table 5 presents the results of the two-way ANOVA test.

Table 5 Results of Two-Way Anova Test

Source of Variance	JK	dk	RJK	$F_{calculated}$	F_{table}	Conclusion
Between Rows (Model) A	45,1348	1	45,1348	7,7788	3,99	H_{0A} rejected
Between Columns (Cognitive Style) B	24215,2067	1	24215,2067	4173,3807	3,99	H_{0B} rejected
Interaction (Model Cognitive Style) A x B	−23804,9732	1	−23804,9732	−4102,6788	3,99	$H_{0A\times B}$ accepted

Based on Table 5, it was found that (1) There is a difference in mathematical communication skills between students who learned using the PjBL (Project-Based Learning) model and those who learned using the discovery learning model, (2) There is a difference in mathematical communication skills between students with a field-independent cognitive style and those with a field-dependent cognitive style, (3) There is no interaction effect between PjBL and cognitive style on mathematical communication skills.

In relevant studies, findings align with this research, showing a difference in mathematical communication skills between students who learned using the PjBL model and those who learned using conventional models. This is consistent with previous research indicating an improvement in students mathematical communication skills when using the Project-Based Learning (PjBL) model [33].

The second result shows a difference in mathematical communication skills between students with a field-independent (FI) cognitive style and those with a field-dependent (FD) cognitive style.

This is in line with relevant research stating that there is a difference in mathematical communication between students with FI and FD cognitive styles [34].

The third result indicates no interaction effect between the PjBL learning model and cognitive style on communication skills. This aligns with relevant studies showing no interaction effect between the learning model and moderator variables on mathematical communication skills [35][36][37].

4. CONCLUSIONS AND RECOMMENDATION

(1) There is a difference in mathematical communication skills between students who learn using the PjBL (Project-based Learning) model and those who learn using the discovery learning model. Based on data analysis using a two-way ANOVA test $F_{calculated} > F_{table}$ specifically $7{,}7788 > 3{,}99$. (2) There is a difference in mathematical communication skills between students with field-independent cognitive styles and those with field-dependent cognitive styles. Based on data analysis using a two-way ANOVA test $F_{calculated} > F_{table}$ specifically $4173{,}3807 > 3{,}99$. (3) There is no interaction effect between the PjBL learning model and cognitive style on students mathematical communication skills. Based on data analysis using a two-way ANOVA test $F_{calculated} < F_{table}$ specifically $-4102{,}6788 < 3{,}99$.

According to the research results, it is proven to address the title of the study, which is the Effect of PjBL (Project-Based Learning) on Mathematical Communication Skills viewed from Cognitive Styles.

Based on the findings of this research, the researcher provides several recommendations, including suggesting that mathematics teachers consider the PjBL (Project-Based Learning) model as one alternative instructional approach in the teaching process and allocate time effectively so that each stage of the PjBL learning model can be optimally implemented.

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