Problem-Based Learning and Discovery-Based Learning Models on Student's Metacognitive Ability Based on Self-efficacy

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Abstract. Problem-solving is an essential basic skill which requires metacognitive abilities. In fact, there are many students who experience metacognitive failure in solving mathematical problems. This study aims to discover the effect of applying Problem-Based Learning, Discovery-Based Learning and Conventional Learning models on students' metacognitive abilities based on self-efficacy in problem solving. This research was conducted in Jambi University, Indonesia. The population of this study were all students who attended Discrete Mathematics lectures for the 2022/2023 academic year, and all members of the population were sampled in this study. Problem-Based Learning, Discovery-Based Learning and Conventional Learning model became the independent variables, while the dependent variable was the students' metacognitive ability in solving mathematical problems. The research instruments were self-efficacy questionnaires, pre-test questions, learning model implementation sheets and post-test questions which had been validated. It employed a quasi-experimental research design with a randomized block design and applied Two-Way ANOVA to analyse the data. The results showed that there was an effect of Problem-Based Learning, Discovery-Based Learning and Conventional Learning models on students' metacognitive abilities based on self-efficacy in problem solving.

Keywords: Metacognitive ability · Problem Based Learning · Discovery-Based Learning · Conventional Learning · Self-efficacy

1 Introduction

1.1 Background

Problem-solving is a basic skill needed by students today [1]. Problem-solving is a very important component of mathematics education. By solving problems, students are expected to acquire ways of thinking in solving problems, have curiosity, and perseverance in studying a problem and can solve problems outside the classroom [2].

Gagne & Smith [3], problem-solving is a type of learning to think in higher order which is more complex than other types of learning to think. Problem-solving selects and establishes unique rules in solving problems, so that it can form a higher-order thinking

R. N. Indah et al. (Eds.): AICOLLIM 2022, ASSEHR 725, pp. 523–535, 2023.
https://doi.org/10.2991/978-2-38476-002-2_50

structure that was not previously owned by students. Gagne stated, "Problem solving is higher order and more complex type learning than rule-learning, and rule acquisition is perquisite to problem solving. Problem solving involves selecting and chaining sets of rules in a manner unique to the learner which results in establishment of a higher order set of rules which was previously unknown to the learner."

Polya [4] stated that problem solving is a means to seek understanding from things that are not clear into something clearer. Therefore, in problem solving, a way is needed to understand, solve, and reflect on the problem so that the right results are obtained. Furthermore, Polya [4] states that problem solving is a special ability that requires one's intelligence.

Sakshang & Olson said that when students face a mathematical problem, students cannot immediately find a solution but must determine strategies to solve the mathematical problem. This is confirmed by Musser et al. [5] that math problems are different from practice questions. Practice questions can be solved using routine procedures, while math problems can be solved using non-routine procedures. As a result, students who will solve the problem can first reflect on the problem to be solved.

Problem solving activities are closely related to metacognition. Metacognition is an important dimension in problem solving because it includes awareness, monitoring, and regulation of one's cognitive processes [6]. In addition, Hassan & Rahman state that problem solving skills and metacognitive awareness have an important role in improving the mathematics achievement of high school students. Thus, it can be said that the metacognitive process can help someone in solving mathematical problems effectively and meaningfully because problem solving requires mental processes by involving awareness and self-regulation of thinking.

Metacognition is thinking to think [7–10] and the component of metacognition consists of metacognitive knowledge and metacognitive regulation [11, 12]. Metacognition refers to two areas, namely knowledge about cognition and regulation of cognition [9, 13]. Metacognition refers to students' awareness of their own cognitive processes and the regulation of those processes to achieve certain goals [14]. Metacognition as a person's ability to understand and monitor their own learning, and how to use specific learning strategies in problem solving [15]. Some researchers conclude that metacognitive processes can improve problem solving outcomes [16, 17].

There is a relationship between metacognitive skills with student learning outcomes. Taraban, et al. [18] stated that metacognitive strategies can improve student academic achievement. Additionally, Oszoy & Ataman [19] stated that metacognition can be used as a useful tool to develop student problem solving skills and metacognitive processes can improve problem solving outcomes [16, 17]. According to Magiera & Zawojewski [20], there is a positive relationship between metacognitive activities and the implementation of problem solving.

The process of metacognition in a person depends on his metacognitive activity. The higher a person's level of metacognitive activity, the easier it is to solve problems. According to [20], there are three metacognitive activities, namely (1) metacognitive awareness which relates to individual awareness where they are in the learning process or in the problem solving process, (2) metacognitive evaluation refers to a decision on the effectiveness of individual thinking about the strategy chosen, and (3) metacognitive regulation occurs when individuals modify their thinking in solving problems.

The metacognitive process is very important in solving mathematical problems, even though students are already metacognitive but there are still metacognitive failures in solving these mathematical problems. Goos [17] states that there are 3 metacognitive failures in solving mathematical problems, namely (1) metacognitive blindness, (2) metacognitive vandalism and (3) metacognitive mirage.

Based on the results of preliminary observations that the researchers conducted on 30 students of the Mathematics Education Study Program, FKIP Jambi University in October 2021, it was observed that 20 students experienced metacognitive failure in solving mathematical problems. Metacognitive failure occurs when students perform metacognitive regulation by changing the context of the problem to fit the concept of knowledge they have, namely by depicting a triangle in a square which results in metacognitive vandalism.

Several alternatives to solve the problem of students' metacognitive failure in solving math problems already carried out, including providing scaffolding (assistance) to students. However, there is weakness is the provision of scaffolding can conducted individually and not all students who experience failure metacognitive could assisted. Because of researcher will using the learning model-based problem in classroom learning. The learning model that will writer apply are Problem-Based Learning models and Discovery-Based Learning models.

Problem Based Learning learning model is a learning model used for look for solution problems in the real world. Learning model developed for help lecturer develop thinking skills and problem-solving skills during lesson. Besides, the lecturer could provide a stimulus in the form of problem so the student could solving it inorder to increase metacognitive student [21–23].

Learning Model Discovery Learning is the model used for solve problem by intensive under lecturer supervision. In Discovery-Based Learning, lecturer guide student to answer or solve a problem. Discovery-Based learning is a learning method which demanding lecturer to be more creative in creating situations that can make students actively study to find their own knowledge [23–25].

Based on the description above, researchers need to do study using the Problem-Based Learning and the Discovery-Based Learning as the learning models to increase ability metacognitive student in solving problem math.

1.2 Research Problem

The following are the problems in this study.

1. Did PBL and DBL methods influence the students' metacognitive ability based on self-efficacy in solving mathematical problem?
2. Were there any differences in the metacognition ability in solving problem mathematics based on high, medium, and low self-efficacy among students?
3. Was there any interaction between the application PBL and DBL towards the students' metacognitive ability based on their self-efficacy in solving mathematical problem?

1.3 Research Purpose

The purposes of this research are:

1. To find out the influence of PBL and DBL methods influence the students' metacognitive ability based on self-efficacy in solving mathematical problem.
2. To figure out the differences in the metacognition ability in solving problem mathematics based on high, medium, and low self-efficacy among students.
3. To find out the interaction between the application PBL and DBL towards the students' metacognitive ability based on their self-efficacy in solving mathematical problem.

2 Research Methods

2.1 Research Design

This study is quasi-experimental research (Creswell, 2012) and applied nonequivalent control group design, which shared group study into group experiment and group control, then each group given treatment. After that, each group given posttest to measure the ability of solving problem (Tables 1 and 2).

O_1 = Pre-test result in class Experiment I
O_2 = Post-test results in class Experiment I
O_3 = Pre-test results in class experiment II
O_4 = Post-test results in class experiment II
O_5 = Pre-test results in class control
O_6 = Post-test results in class control
X_1 = Treatment in class Experiment I
X_2 = Treatment in class Experiment II
X_3 = Treatment in class Control

Description:

PR: Low self-efficacy student's solving problem ability with PBL
PS: Intermediate self-efficacy student's solving problem ability with PBL
PT: High self-efficacy student's solving problem ability with PBL
DR: Low self-efficacy student's solving problem ability with DBL
DS: Intermediate self-efficacy student's solving problem ability with DBL

Table 1. Design Study Description

Class	Pretest	Treatment	Posttest
Experiment 1	O_1	X_1	O_2
Experiment II	O_3	X_2	O_4
Control	O_5	X_3	O_6

Table 2. Linkages Between Variable

Self-Efficacy	Learning		
	Problem Based Learning (P)	Discovery-Based Learning (D)	Conventional Learning (K)
Low	PR	DR	KR
Intermediate	PS	DS	KS
High	PT	DT	KT

Table 3. The number of Population

No.	Class	Amount
1.	R001	32
2.	R002	37
3.	R003	34
Amount		**103**

DT: High self-efficacy student's solving problem ability with DBL

CR: Low self-efficacy student's solving problem ability with conventional learning method

KS: Intermediate self-efficacy student's solving problem ability with conventional learning method

KT: High self-efficacy student's solving problem ability with conventional learning method.

2.2 Population and Sample

Population in study this is whole Semester 3 students of Mathematics Education FKIP Jambi University enrolled in the 2021/2022 class (Table 3).

Based on pre-test results, it is obtained student the three classes have the same metacognitive ability. Total sampling was applied, resulting in all member of the population was taken as the sample.

2.3 Research Instrument

Instrument is a tool measure used to obtain data on research. The research instruments used in study this are (a) self-efficacy questionnaire, (b) observation sheet about the implementation Learning Problem Based Learning, Discovery Learning and Conventional, and (c) pretest and posttest questions of metacognitive ability. Instruments used in this study was validated by the validators. Besides, the researchers use the form of self-efficacy question, which is designed based on self-efficacy indicators, to find out self-efficacy. The researchers also used observation form from the implementation of Problem Based Learning, Discovery Learning and conventional learning model.

2.4 Data Analysis Techniques

Data that is analyzed in this research was data from the pretest and posttest of problem solving and self-efficacy ability of controlled group students, experiment I, and class experiment II. Pretest data was used for see the ability of the student before the treatment was given in the topic of Sequence and Series. Meanwhile, the posttest data was used for hypothesis test. Pre-requisite test used were a normality test and homogeneity of variances test. For testing the research hypothesis, the researchers use two-way ANOVA with interaction with level significant (α) 0.05. The researchers were using SPSS software version 25 for the next calculation.

The linear model of the two-way ANOVA model is:

$$\mathbf{Y_{ij}} = \boldsymbol{\mu} + \boldsymbol{\tau_i} + \boldsymbol{\beta_j} + \in_{\mathbf{ij}}\ , \tag{1}$$

i = 1, 2,3…… t
j = 1, 2, 3,…. τ_i.

Description:

Y_{ij} = observation value of treatment i in group j.
μ = population mean
τ_i = additive effect of the i-th treatment
β_j = additive effect of j group
$\in_{ij}$ = Effect of experimental error from treatment i on group j.

3 Results and Discussion

3.1 Research Results

3.1.1 Implementation of Learning Model

Implementation of the Learning Model used in study this could be seen in Table 4.

3.1.2 Pretest Value

Pretest data was obtained from the results of the students' metacognitive ability test before student learn Mathematics Discrete. The following is the pretest score obtained (Table 5).

The students' pre-test average score with PBL, DBL and Conventional learning are 15.06, 16.60 and 16.05 consecutively. Statistically the average values of the pretest above are same. It could be seen from the SPSS result using ANOVA that we get sig = 0.888 when $\alpha = 0.05$, hence sig value > α value. Therefore, we can conclude that pretest scores for the sample groups have the same metacognitive ability at the beginning of the research, could be seen in Table 6.

Table 4. Implementation of Problem Based Learning, Discovery Learning and Conventional Learning Models.

LEARNING MODEL					
Problem-Based Learning	Percentage (%)	Discovery-Based Learning	Percentage (%)	Conventional	Percentage (%)
Orient student with contextual problem	85	Principle of solving problem	92	Convey learning topic	90
Organize student to find himself the theory concept	85	Principle of management learner	87	Give student opportunity to practice and provide guidance	85
Direct student to solve problem	85	Principle integrate and connect	90	Check the understanding and feedback	85
Presenting the problem-solving results	85	Principle of analysis and interpretation information	88	Give opportunity for continuation training and its application	86
Analyze and evaluate problem solving results	87	Principle of failure and feedback	90		

Table 5. Data of metacognitive ability based on pretest (Descriptive Statistics)

	N	Min	Max	Mean	Std. Deviation
KON pretest	31	0	20	15.06	3.076
PBL Pretest	34	0	22	16.60	3.360
DL pretest	37	0	23	16.55	3.589
Valid N (listwise)	31				

3.1.3 Student Self Efficacy Data as Research Sample

Students' Self-Efficacy Test Results which applied the Problem Based Learning (PBL), Discovery Learning and Conventional learning models could be seen in Table 8. It can be seen that there were 15 high self-efficacy students, 54 intermediate self-efficacy student, and 28 low self-efficacy students (Table 7).

Table 6. ANOVA test results for the pretest data from the sample groups.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.669	2	1.334	.119	.888
Within Groups	1021.799	91	11.229		
Total	1024.468	93			

Table 7. Average Group Self Efficacy Test Results Sample Study

Method	SE	Mean	Std. Deviation	N
Problem Based Learning	High	91.25	9.543	6
	Intermediate	74.44	9.532	19
	Low	56.00	5.477	9
	Total	75.81	14,382	34
Discovery-Based Learning	High	93.33	6.124	7
	Intermediate	79.44	10.130	25
	Low	82.50	18.484	5
	Total	83.87	11.882	37
Conventional Learning	High	81.67	18.930	2
	Intermediate	71.47	8.797	15
	Low	57.92	9.405	14
	Total	67.34	12.571	31
Total	High	90.75	10.166	15
	Intermediate	75.19	9.902	59
	Low	62.14	14,454	28
	Total	75.59	14,533	102

Table 8. Metacognitive Ability based on Posttest

Model Learning	mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Problem-Based Learning	44.68	1.133	47.465	52.970
Discovery-Based Learning	49.29	1.284	47.558	51.665
Conventional Learning	31.39	1.267	29.405	33.441

Table 9. Normality test results based on post-test data (One-Sample Kolmogorov-Smirnov Test)

N		KON class	PBL class	DL class
		31	37	34
Normal Parameters[a,b]	mean	31.39	44.68	49.29
	Std. Deviation	8.065	8.330	6.525
Most Extreme Differences	Absolute	.150	.197	.133
	Positive	.094	.190	.133
	negative	.150	.197	.083
Kolmogorov-Smirnov Z		.833	1.201	.778
asymp. Sig. (2-tailed)		.491	.112	.581

[a] Test distribution is Normal.
[b] Calculated from data.

3.1.4 Data of Metacognition Ability Based on Posttest

The students' metacognitive ability after learning with the PBL, the DBL and the conventional learning could be seen in the Table 8.

It is clear that the average score of the sample groups' metacognitive ability using the PBL, the DBL and Conventional learning are 44.68, 49.29 and 31.39 consecutively. Next, an assumption testing was needed to be conducted for using the two-way ANOVA test.

3.1.5 Assumption Test from ANOVA Two-Way Direction Test

3.1.5.1 Assumption of the Metacognitive Ability Test Based on Posttest Scores

H_0: Sample data originated from normally distributed population.
H_1: Sample data originated from normally distributed population.

Normality test results from students' metacognitive ability could be seen in Table 9.

Based on SPSS output for normality test, each metacognitive ability data based on posttest questions the PBL, the DBL and Conventional learning are 0.491, 0.112 and 0.0.851 consecutively. For $\alpha = 0.05$, we get significant score more than 0.05. Thus, the data was capable metacognitive spread normally.

3.1.5.2 Assumption of Metacognitive Capability Based on Posttest Score with Homogeneity of Variances

Hypothesis:
H_0: Sample data have homogeneous variance
H_1: Sample data have variance that is not homogeneous

Based on the SPSS output in the Test of Homogeneity of Variances table, it is obtained score significance of 0.375. For = 0.05, we get score significant bigger from value. With

Table 10. Homogeneity of Variance Result based on Students' Metacognitive Capability Post-test Score

	Levene Statistics	df1	df2	Sig.
Score	.991	2	99	.375
Self-Efficacy	1.559	2	99	.215

Table 11. SPSS output for Two-Way ANOVA Direction (Tests of Between-Subjects Effects)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5989,441[a]	8	748,680	12,829	,000
Intercept	115078,526	1	115078,526	1971,909	,000
Learning Model	2578,490	2	1289,245	22,092	,000
Self-Efficacy	107.274	2	53.637	,919	, 04 2
Model * Self-Efficacy	262.178	4	65.544	1.123	, 021
Error	5427,382	93	58,359		
Total	192860,000	102			
Corrected Total	11416.824	101			

[a] R Squared =,525 (Adjusted R Squared =,484)

thereby could concluded that ability data metacognitive student has the same variance. This thing could be seen from Table 10.

3.1.6 Hypothesis Test Results

Based on the assumption test results for using two-way ANOVA, the data of students' metacognitive ability was originally from normal distributed population and the variance of students' metacognitive ability data was homogeneous. Hence, two-way ANOVA could be applied for finding the influence of the application of the PBL and the DBL towards the students' metacognitive ability based on self-efficacy in solving mathematical problem. SPSS output for testing the hypothesis could be seen in Table 11.

By using Tests of Between-Subjects Effects table, the significance score of PBL was 0.000. For $\alpha = 0.05$ we got a significance score much less than α. It shows that the PBL, the DBL and Conventional learning were very effective for students' metacognitive ability in solving mathematical problem.

Furthermore, significance score of self-efficacy was 0.042. For $\alpha = 0.05$, we get significance score smaller from α, which means that self-efficiency had an influence in students' metacognitive ability for solving mathematical problem. Likewise, the Learning Model * Self Efficacy obtained 0.021 and significance score smaller from α. It means that the Learning Model and Self Efficacy had an effect to students' metacognitive ability.

Table 12. Duncan Advanced Test Result

Learning	N	Subset		
		1	2	3
Conventional	31	31.39		
PBL	37		44.68	
Discovery Learning	34			49.29
Sig.		0.000	0.000	0.000

For finding out the difference of the effect of learning model to students' metacognition ability in solving mathematical problem, Duncan 's Advanced Test showed that there were differences among the PBL, the DBL and Conventional Learning to students' metacognitive ability. Duncan Advanced test results can be seen in the Table 12. There were differences of the effect between the PBL and the DBL, the PBL and the Conventional learning, and the DBL and the Conventional learning on students' ability metacognitive in solving mathematical problem.

3.2 Discussion

Among the three learning models used in this study, it can be seen that the implementation of the Discovery-Based Learning is greater in percentage than the Problem Based Learning and Conventional learning. The Discovery-Based Learning is very appropriate to be used to improve students' mathematical problem-solving abilities. This is aligned with the opinion of Herdiana et al. (2017) that the Discovery-Based learning is effective for improving students' mathematical problem-solving abilities.

Based on the results, it was found that the metacognitive abilities of students using the Problem-Based Learning were different from the ones using the Discovery Learning. This is because at the time of the research, the material taught was the introduction of Bolean Algebra which is related to understanding the concept of the topic. This is in accordance with the opinion of Sinambela, et al. [26] that there is an influence of the discovery learning model on the concept of students' mathematical understanding.

4 Conclusion and Suggestion

4.1 Conclusion

There is a difference in the effect of the Problem-Based Learning and the Discovery-Based Learning on students' metacognitive abilities in solving mathematical problems.

There is a difference in the effect of Problem-Based Learning and Conventional learning on students' metacognitive abilities in solving mathematical problems.

There is a difference in the effect of the Discovery-Based Learning and the Conventional learning on students' metacognitive abilities in solving mathematical problems.

4.2 Suggestion

Based on findings research, the researchers hope that the other lecturers could using Problem-Based Learning and Discovery-Based Learning in order to increase students' ability in solving mathematical problem.

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