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Improving critical thinking skills in business mathematics lectures through problem base learning

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ABSTRACT

Students' mathematical critical thinking skills have not been optimally developed. Skill development is done through PBL (Problem Base Learning) strategy. The study aims to determine the impact of PBL on critical thinking skills using an experimental design with a control group. Business students who were taking Business Mathematics courses in Bandung city became the population. The research sample was 107 first semester business students who were taking mathematics courses. The sample was randomly selected by class. The research instrument was developed by the researcher and was in the form of a test with moderate difficulty and good differentiating power, high validity and reliability. Data were analyzed by one and two-way ANOVA. The results of the study: (1) the critical thinking ability of students who learn through PBL is better than those who learn conventionally, (2) the critical thinking ability of students with high, medium and low initial abilities who learn through PBL is not better than those who learn conventionally, (3) the effect of learning on critical thinking ability does not depend on initial ability, (4) the attitude of students who learn through PBL is more positive than those who learn conventionally.

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1. INTRODUCTION

Applied and reasoning aspects of mathematics as one of the basic sciences have an important role in mastering science and technology. Mathematics learning is expected to be able to foster critical thinking skills and reasoning power of students. Acculturation of reasoning will be achieved if efforts to organize student reasoning go well so that it can lead to the habit of reasoning (Soedjadi, 1994: 2).

Mathematics learning is intended to: (1) train the way of thinking and reasoning in drawing conclusions, for example through investigation, exploration, experimentation, showing similarities, differences, consistency, and inconsistency, (2) develop creative activities that involve imagination, intuition, and discovery by developing divergent thinking, originality, curiosity, making predictions and conjectures, and trial and error, (3) develop problem solving skills, and (4) develop the ability to convey information and communicate ideas, among others through oral speech, notes, graphs, maps, diagrams, in explaining ideas (Ministry of National Education 2003: 6).

Learning in higher education is defined as programmed activities in the design of facilitating, enpowering, and enabling (FEE), to make students learn actively, which emphasizes learning resources. In addition, learning is also seen as a process of developing thinking creativity in order to: (1) improve thinking skills, (2) increase knowledge, and (3) construct new knowledge as an effort to improve mastery and development of lecture material (Ministry of National Education, 2003: 6); Directorate of Academic Development and Student Affairs (2005b: 11).

Especially in universities in the field of business, mathematics learning is directed at scientific activities so that students are creative, innovative and can build their own understanding and emphasize more on explaining and explaining the important role of mathematics in understanding, exploring and developing accounting, finance and management (Johanes and Handoko, 1988; Dumairy, 1991). According to Sumarmo (2002). learning business mathematics to meet the needs of the present is emphasized on understanding the concepts needed to solve mathematical problems and other sciences while meeting future needs is emphasized on the ability to reason logically, systematically, critically, and carefully and think objectively and openly.

The direction and emphasis of mathematics learning as stated by Johanes and Handoko (1998); Dumairy (1991); Sumarmo (2002) is quite reasonable because approaching a problem, understanding problems, solving problems, analyzing problems, simplifying presentations, and making generalizations becomes more efficient and economical if using mathematics. In addition, business mathematics lecturers need to equip students with the skills and ability to select, sort and classify information because students now live in an era of abundant information that is digital and easily obtained (Hidayat, 2010).

According to Wuest and Bucher in Soemosasmito (2001: 7), learning in higher education should be student-centered, which aims to optimize student abilities. The learning atmosphere is flexible, not rigid like a sacred atmosphere, create a pleasant atmosphere, provide opportunities for students to learn according to their respective learning styles. What is equally important is that it is centered on the development of the whole student, which means that learning must involve physical factors, namely physical movement, intellectual emphasis on reasoning power, mental focus on courage, emotional directed towards art in thinking.

Current mathematics learning practices still take place in a teacher centered, teacher telling atmosphere, not yet student centered. In a lecturer-centered class, the role of lecturers is more dominant than students (Hidayat, 2010). According to Marsigit, (2000), mathematics learning needs to take place in a student centered atmosphere and emphasize more on: (1) the connection between the material taught and the situation of everyday life, (2) solving real problems by trial and error, (3) thinking how a formula or procedure is found, (4) ways or steps to solve problems (5) the role or usefulness of mathematics in life now and in the future (NCTM 2000), Ministry of National Education, 2003a), Ministry of National Education (2003b) Directorate of Academic Development and Student Affairs (2005a),

Low learning outcomes are caused by: (1) learning objectives that are not formulated appropriately, (2) learning processes that are misdirected but not realized, (3) inappropriate material, and the material provided in mathematics courses in business colleges is only basic mathematics followed by application with emphasis on calculations or finding solutions, but forgetting conclusions about the relationship between variables (Mulyono, 1996). Meanwhile (Furqan et al., 2019) the causes of low student learning outcomes are: (1) learning models that are less interesting; (2) media that are not varied, (3) boring learning methods, (4) students are still classified as passive, and (5) lecturers only explain by giving formulas and going directly to sample problems.

To overcome the learning problems and learning outcomes stated above, especially improving critical thinking skills, researchers apply the Problem Based Learning (PBL) learning model in business mathematics lectures. According to (Furqan et al., 2019). PBL is learning that presents contextual problems for students to solve and learning through PBL can train students' abilities and skills in solving a problem.

Research related to PBL and critical thinking over the past eight years provides the following results: (1) The PBL approach can develop the critical thinking skills of Mathematics Education students of IKIP Budi Utomo Malang. students are more active during the learning process, more creative, and responsive in solving the problems given (Zamzam, 2016), (2) PBL is effective in improving students' critical thinking skills in subjects (Anggit, 2020), (3) the highest increase in critical thinking skills is in the skill indicator of providing explanations and the lowest in the matching indicator (self-regulation) (Fadhilah, 2022), (4) Student activity during the learning process through PBL takes place very well. The results of error analysis show that the most mistakes made by students are errors in writing the final answer. This is due to students' mistakes in working on the previous stage and also students who do not write conclusions (Yuliana, 2021).

On the basis of the above explanation, the researcher examines improving critical thinking skills in mathematics lectures through Problem Base Learning with the hypotheses to be tested: (1) The critical thinking skills of students who learn through PBL are better than those who learn conventionally (2) In terms of students' initial abilities, the critical thinking skills of students who learn through PBL are better than those who learn conventionally, (3) there is an interaction between learning factors and initial abilities on critical thinking skills (4) there are differences in student attitudes towards learning mathematics through PBL between PBL-P, PBL-NP and Conventional class students.

2. METHODS

1. Research Design

This study used an experimental design using a control group (Ruseffendi, 2005). In addition to the learning factor (PBL and conventional), another factor included in this study was students' initial ability. The initial ability was grouped into good, medium, and low. The grouping was based on the test results with the SAT instrument. Students' initial ability was only measured in terms of Mathematical Reasoning. This research involves learning and initial ability variables. Learning acts as the independent variable, initial ability as the control variable.

Table 1. Research design

Group	Pretest	Treatment	Posttest	Description
Experiment I (R)	O	X	O	PBL-NP
Experiment II (R)	O	X	O	PBL-P
Control	O	-	O	

Description: R = random, X = learning with PBL, O = Pretest and posttest to measure mathematical critical thinking skills, PBL-NP = learning through PBL Non Grouping, PBL-P = learning through PBL Grouping.

2. Research Procedure

The research procedures are (1) determining the population subject and sample subject, (2) compiling teaching materials with the subject matter: a) function, b) function derivative, and c) matrix, (3) making critical thinking ability instruments for each subject matter, (4) asking 6 lecturers to weigh the critical thinking ability questions, (5) testing the results of the weighing with Q-Cohran statistics, (6) trying the instrument to students who are taking the Short Semester, (7) analyzing the test results by checking: a) validity of the instrument, b) reliability of the instrument, c) difficulty level of each question, d) differentiating power, (8) selecting experimental groups and control groups by random class, (9) testing initial ability using SAT so that students can be grouped in high, medium, and low initial ability, (10) implementing learning through PBL in experimental and conventional classes, (11) carrying out postes after each subject. The post-test used critical thinking skills type questions.

After the experiment was completed, it was continued by analyzing the pretest and posttest data by: (1) making a description of the initial ability of students who learn through PBL and conventional, (2) marking students who have good, medium, and low abilities, (3) making a description of: a) learning through PBL, b) critical thinking skills, and c) student attitudes. (4) testing the normality and homogeneity of learning outcomes: (2) critical thinking skills. Data normality is seen from the Kolmogorov-Smirnov test results. Homogeneity is seen from the results of the Levene test, (5) test the differences in critical thinking skills of students who learn through PBL and conventional. Testing using two-way ANOVA, (6) analyzing the interaction between learning factors and initial abilities on critical thinking skills. The analysis is based on the two-way ANOVA output and interaction diagram, (7) analyzing the validity and reliability of data on attitudes, (8) making a report on the results of the study.

3. Research Subjects

The population subjects were first semester students in the city of Bandung who took Business Mathematics courses. The research sample of the first and second classes as experimental classes and the third class as a control class.

Students in the first class received learning through PBL Grouping. The second class learned through BL Non-Grouping, the third class learned conventionally. The basis of grouping is the initial ability of students, namely T (High), S (Medium), R (Low). The number of subjects in the PBL class was 36 students each while in the conventional class 35 students. Thus, this study involved 107 students. Schematically, the variables and factors that will be studied in the experiment can be seen in Table 2.

Table 2. Linkages between Research Variables

Ability Initial	Learning			
	PBL		Conventional	
	Critical Thinking Ability	Student Attitude	Critical Thinking Ability	Student Attitude
T	μ_{12}	μ_{13}	μ_{14}	μ_{15}
S	μ_{22}	μ_{23}	μ_{24}	μ_{25}
R	μ_{32}	μ_{33}	μ_{34}	μ_{35}

Description: μij = learning outcomes of critical thinking skills based on the i-th row and j-th column. For example, μ22 states the critical thinking ability of the group of students with moderate initial ability and learning through PBL. T = High, S = Medium, R = Low.

4. Development of Research Instruments

The instruments used in this study were in the form of tests and non-tests. Non-test instruments in the form of Likert model attitude scale. Indicators of students' attitudes towards learning mathematics through PBL are based on the Directorate of General Secondary Education (2003).

3. RESULTS AND DISCUSSION

1. Description of Initial Ability of All Learning Groups

The description and distribution of initial ability and number of subjects in each learning class and initial ability are shown in Table 3.

Table 3. Number of Students and Initial Ability of Research Subjects

Group	Initial ability			Total
	High	Medium	Low	

PBL- NP	6 (16,7%)	13 (36,1%)	17 (47,2%)	36 (100%)
PBL-P	5 (13,9%)	12 (33,3%)	19 (52,8%)	36 (100%)
Convensional	6 (17,1%)	16 (45,7%)	13 (37,1%)	35 (100%)
Total	17	41	49	107

In Table 3, it can be seen that students with low initial ability were most abundant in the PBL-P and PBL-NP classes. The students with good initial ability were evenly distributed across the three classes. In each class, students with moderate and low initial abilities are more than students with good initial abilities.

2. Description of Initial Critical Thinking Ability Score

The description of the initial value of critical thinking skills and the number of subjects in each learning class is shown in Table 4.

Tabel 4. Deskripsi Nilai Awal Kemampuan Berpikir Kritis

Group	N	Mean	Std. Deviation	Minimum	Maximum	Q1	Q3
PBL- NP	36	46.6667	18.36145	10.00	80.00	30	60
PBL-P	36	55.2778	15.39687	30.00	90.00	50	60
Convensional	35	40.2857	15.43215	20.00	70.00	30	50

Table 4 shows that the average value of critical thinking skills of students who learn through PBL-P is greater than those who learn through PBL-NP. The mean value of critical thinking skills of students who learn through PBL-NP is greater than students who learn conventionally. This means that the average value of critical thinking skills of students who learn through PBL grouping is the best.

Compared to the non-grouping and conventional PBL classes, the standard deviation of the PBL-P class is the smallest. This means that the value of critical thinking skills of students who learn with PBL-P is more clustered around the average value. The smallest value of students in PBL-P and non-grouping classes is 30 and 10 respectively while the smallest value for the conventional class is 20. This means that the lowest value of the PBL-P class is above the smallest value of the conventional and PBL-NP classes. In addition, Table 5 also shows that students who learned through PBL can reach the maximum score of 90 while students in the conventional class cannot reach 90, at most 70.

The first and third quartile values of the PBL-NP class are 30 and 60. This means that 25% of the total PBL-NP class students, or 9 students, scored below 30 and 9 students scored above 60. The first and third quartile values of the PBL-P class are 50 and 60. This means 25% of the total students of the PBL-P class or 9 students, scored below 50 and there were 9 students who scored above 60. The first and third quartile values of the conventional class are 30 and 50. This means 25% of the total students of the conventional class or 9 students scored below 30 and there were 9 students who scored above 50.

3. Validity and Reliability of Critical Thinking Ability Instrument

The validity and reliability of the critical thinking skills instrument processed with SPSS 26 are shown in Table 5.

Table 5. Validity and Reliability of Critical Thinking Skills Instrument

Cronbach's Alpha	N of Items
.764	3

Item-Total Statistics

Critical Thinking Ability	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted

Function	22.69	82.692	.525	.759
Derivative	25.00	82.895	.450	.850
Matrix	21.54	64.676	.860	.372

In Table 5 it can be seen that the Cronbach's Alpha value = 0.764, meaning that the reliability of the critical thinking instrument is high (Guilford in Ruseffendi (2005)) and all critical thinking ability questions have high validity because the Corrected Item-Total Correlation value is more than 0.312 (Santoso, 2000), (Priyatno, 2009). Table 6 also shows that the question of critical thinking ability in the subject matter of derivatives (Kps2) needs to be revised or replaced because it has a Cronbach's Alpha if Item Deleted value of 0.850 which is greater than 0.764 (Cronbach's Alpha value). The questions Kbks1 and kbks3 can be used to collect data on critical thinking skills.

4. Validity and Reliability of Attitude Instruments

The validity and reliability of the attitude instrument processed with SPSS 26 are shown in Table 6.

Table 6. Validity and reliability of attitude instruments

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.672	.685	10

	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Items 1	.298	.655
Items 2	.259	.661
Items 3	.280	.658
Items 4	.423	.630
Items 5	.464	.628
Items 6	.336	.652
Items 7	.462	.624
Items 8	.294	.657
Items 9	.338	.647

Table 6 shows that the value of Cronbach's Alpha = 0.672. This indicates that the reliability of the attitude instrument is moderate (Guilford, in Ruseffendi, 2005).

5. Hypothesis Testing

Testing the three hypotheses proposed in this study using posttest data with two-way ANOVA.

Normality Test

The recapitulation of the results of the normality test of critical thinking ability scores with the Kolmogorov-Smirnov test is shown in Table 7.

Table 7. Kolmogorov-Smirnov Test Results for Each Group and Ability

Group		Critical Thinking Ability
PBL-NP	Kolmogorov-Smirnov Z	.930
	Asymp. Sig. (2-tailed)	.353
PBL-P	Kolmogorov-Smirnov Z	1.305
	Asymp. Sig. (2-tailed)	.066
Convensional	Kolmogorov-Smirnov Z	1.041
	Asymp. Sig. (2-tailed)	.228

In Table 7, it can be seen that the Kolmogorov-Smirnov Z values for PBL-NP, PBL-P, and conventional classes are 0.930, 1.305, and 1.041, respectively, greater than Dtabel = 0.226667. Similarly, the value of Asymp. Sig. (2-tailed) for PBL-NP, PBL-P, and conventional classes are 0.353, 0.066, and 0.228 respectively, greater than 0.05. This means that Ho is accepted or the population distribution of critical thinking ability scores of PBL and conventional groups is normal.

Homogeneity Test

The recapitulation of the results of the homogeneity test of critical thinking ability scores with two-way ANOVA is shown in Table 8. In SPSS 26, the homogeneity of a data distribution can be seen from the Levene Statistic value (F_{count}).

Tabel 8. Results of Homogeneity Test for Critical Thinking Ability

Ability	Levene Statistic	df_1	df_2	Sig.
Critical Thinking	1.730	8	98	.101

Table 8 shows that the Levene Statistics (Fcount) value of critical thinking ability is 1.730, below the Ftable = 2.02. Similarly, the sig value. Critical thinking ability = 0.101 above 0.05. This means Ho is accepted or the variances of the three populations are identical. In other words, the population distribution of critical thinking ability scores is homogeneous.

Description of Critical Thinking Ability Learning Results

Experimental data on critical thinking skills of students who learn through PBL and conventional learning processed with SPSS 26 are shown in Table 9.

Table 9. Description of Critical Thinking Ability of PBL and Conventional Groups

Class	Initial Ability	Mean	Std. Deviation	N
PBL-P	High	71.6667	22.28602	6
	Medium	52.3077	10.12739	13
	Low	51.7647	12.86239	17
	Total	55.2778	15.39687	36
PBL-NP	High	44.0000	16.73320	5
	Medium	50.8333	21.93309	12
	Low	44.7368	16.78902	19
	Total	46.6667	18.36145	36
Convensional	High	43.3333	16.32993	6
	Medium	39.3750	14.81834	16
	Low	40.0000	16.83251	13
	Total	40.2857	15.43215	35
Total	High	53.5294	22.34423	17
	Medium	46.8293	16.79866	41
	Low	45.9184	15.93193	49
	Total	47.4766	17.43416	107

In Table 9, it can be seen that the mean value of critical thinking skills of students who have good, medium, and low initial abilities who are in the PBL-P class is better than students in the PBL-NP class. Likewise, the mean value of students with good, medium and low initial abilities who are in the PBL-NP class is better than students who are in the conventional class. The value of critical thinking skills of PBL-P class students with moderate and low initial ability is more clustered around the mean because the standard deviation is smaller than the standard deviation of the value of students with high initial ability.

Testing hypotheses 1, 2 and three is based on experimental data on critical thinking skills through PBL with two-way ANOVA processed by SPSS 26. The two-way ANOVA table processed by SPSS is shown in Table 10.

Table 10. ANOVA of Critical Thinking Ability

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6345.096[a]	8	793.137	3.004	.005	.197
Intercept	203140.190	1	203140.190	769.423	.000	.887
Learning	4818.922	2	2409.461	9.126	.000	.026
Initial Ability	701.417	2	350.708	1.328	.270	.157
Learning * Initial Ability	1483.826	4	370.957	1.405	.238	.054
Error	25873.596	98	264.016			
Total	273400.000	107				
Corrected Total	32218.692	106				

Testing Hypothesis I, the critical thinking skills of students who learn through PBL are better than those who learn conventionally. The null hypothesis - Ho - to test the first hypothesis is that there is no difference in critical thinking skills between PBL-P, PBL-NP, and conventional classes. The alternative hypothesis - H1 is that there is a difference in critical thinking skills between PBL-P, PBL-NP, and conventional classes. Because the Sig. value in Table 11 in the LEARNING row <0.05 means that H0 is rejected, or there is a difference in the mean critical thinking ability between PBL-P, PBL-NP, and conventional classes. Further Testing of the First Hypothesis. The results of testing the first hypothesis show that there is a difference in the mean critical thinking ability between PBL-P, PBL-NP, and conventional classes, so to find out which is the best of the three learning classes, further testing or Post Hoc Tests with the Scheffe test is carried out. The results of Post Hoc Tests are shown in Table 11.

Table 11. Post Hoc Testing of Critical Thinking Ability

(I) Learning	(J) Learning	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
PBL-P	PBL-NP	8.6111	3.82983	.085	-.9085	18.1307
	Convensional	14.9921*	3.85709	.001	5.4047	24.5794
PBL-NP	PBL-P	-8.6111	3.82983	.085	-18.1307	.9085
	Convensional	6.3810	3.85709	.259	-3.2064	15.9683
Convensional	PBL-P	-14.9921*	3.85709	.001	-24.5794	-5.4047
	PBL-NP	-6.3810	3.85709	.259	-15.9683	3.2064

In Table 11, it can be seen that the Mean Difference (I-J) of PBL-P and PBL-NP is not significant because the value of Sig. = 0.085 is more than 0.05. This means that there is no difference in critical thinking skills between PBL-P and PBL-NP classes. It also appears that PBL-P is significantly different from conventional (note the * sign), so it can be concluded that those who are successful in developing critical thinking skills are PBL-P classes and PBL-NP classes.

Testing the second hypothesis, in terms of students' initial ability, the critical thinking ability of students who learn through PBL is better than those who learn conventionally. The null hypothesis of the second hypothesis is that there is no difference in critical thinking ability between groups of students with high, medium, and low abilities. The alternative hypothesis is that there are differences in critical thinking skills between groups of students with high, medium, and low abilities. Because the Sig. value in the INITIAL ABILITY row in Table 12 is 0.270, greater than 0.05, the test is not significant or the null hypothesis is accepted, meaning that there is no difference in critical thinking ability between high, medium, and low ability students.

Testing the third hypothesis, there is an interaction between learning factors and initial ability on critical thinking skills. Ho of the third hypothesis is that there is no interaction between initial ability and learning on critical thinking ability. H1 is that there is an interaction between initial ability and learning on critical thinking ability. Since the sig. value in the row LEARNING *INITIAL ABILITY in Table 12 is equal to 0.238 more than 0.05, then Ho is accepted or the test is not significant. Thus, there is no interaction between initial ability and learning on critical thinking ability.

Referring to Table 10, Table 11, it appears that the group of students who received mathematics learning through PBL-P had better critical thinking skills than those who received mathematics learning through PBL-NP or conventional. In general, all students with high, medium, and low initial abilities who learnt with PBL strategies, their critical thinking skills developed better than students who learnt conventionally. Particularly for PBL-NP, the critical thinking ability of the group of students with high initial ability was almost no different from the group of high-ability conventional class students. Given that there is no interaction between learning factors and initial ability on critical thinking ability, then initial ability - high, medium, low - and learning - PBL-P, PBL-NP - Conventional - are independent of each other.

Students' Attitude towards Learning through PBL

Validity and Reliability of Student Attitude Instrument

Students' attitudes towards learning are captured by non-test instruments. The results of the pilot test to 35 students showed that the validity and reliability of the attitude instrument of students who learned through PBL were moderate.

Description of Student Attitudes

Students' attitudes towards PBL were measured with a Likert scale of 1 to five. 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 agree, 5 = strongly disagree. student attitudes were measured by 10 indicators: (V1) happy to follow this lesson, (V2) loss if you do not follow this lesson, (v3) feel this lesson is useful, (V4) try to submit assignments on time, (V5) try to understand this lesson, (V6) ask the lecturer if something is not clear, (v7) do exercise questions at home, (V8) discuss the subject matter with friends, (V9) try to have this textbook, and (V10) try to find materials in the library. A representation of the mean student responses to the 10 statements is shown in Figure 1.

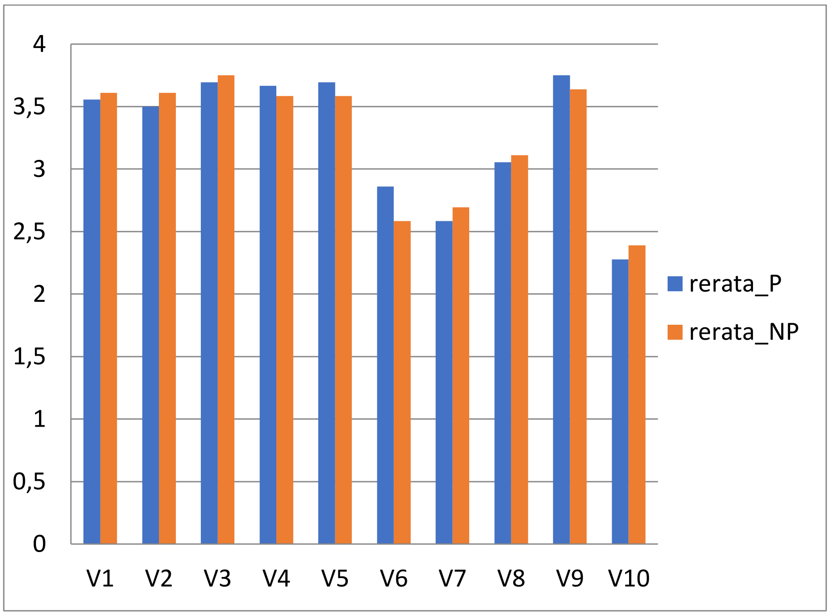

Figure 1. Students' Attitude towards Learning with PBL Grouping and PBL Non-grouping Strategies

From Figure, it can be seen that students' attitude scores towards statements V1 to V5, and V9, are above 3.5. This means that they always or often even enjoy attending lessons, lose money if they do not attend lessons, feel that maths lessons are useful, try to submit assignments on time, try to understand lessons, and try to have textbooks.

Students' attitudes towards statements V6, V7, V8, and V10 are between 2 and 3, this means that asking the lecturer if something is not clear, doing exercise questions at home, discussing subject matter with friends, and trying to find material in the library are rarely done by students.

Testing the fourth hypothesis, there are differences in students' attitudes towards learning mathematics through PBL between PBL-P and PBL-NP class students. Testing differences in student attitudes towards learning mathematics through PBL between PBL-P and PBL-NP class students using the Mann-Whitney test. The Mann-Whitney test was used because the attitude data was ordinal scale. The summary printout of SPSS 26 for the calculation of testing the difference in mean attitudes between PBL-P and PBL-NP classes is shown in Table 12.

Table 12. Summary of Calculation of Attitude Difference Test with Mann-Whitney Test

Variable	Learning	N	Averaged	Mann-Whitney U	Asymp. Sig. (2-tailed)
Happy to follow this lesson- V1	PBL-P	36	3.55	612.000	.635
	PBL-NP	36	3.75		
It's a loss if you don't follow this lesson -V2	PBL-P	36	3.43	567.000	.290
	PBL-NP	36	3.88		
Feel that this lesson is useful-V3	PBL-P	36	3.55	612.000	.601
	PBL-NP	36	3.75		
Try to submit assignments on time-V4	PBL-P	36	3.76	607.500	.580
	PBL-NP	36	3.54		
Trying to understand this lesson-V5	PBL-P	36	3.85	576.000	.330
	PBL-NP	36	3.45		
Ask the lecturer if something is not clear-V6	PBL-P	36	3.95	540.000	.188
	PBL-NP	36	3.35		
Doing exercise questions at home-V7	PBL-P	36	3.48	585.000	.427
	PBL-NP	36	3.83		
Discussing the subject matter with friends-V8	PBL-P	36	3.58	621.000	.740
	PBL-NP	36	3.73		
Trying to have this textbook-V9	PBL-P	36	3.78	603.000	.516
	PBL-NP	36	3.53		
Trying to find materials in the library-V10	PBL-P	36	3.47	583.000	.417
	PBL-NP	36	3.83		

Ho of the fourth hypothesis is that there is no difference in students' attitude towards learning mathematics through PBL between PBL-P, PBL-NP and Conventional classes. H1 there is a difference in students' attitude towards learning mathematics through PBL between PBL-P and PBL-NP class students.

In Table 12, it can be seen that all Asymp. Sig. (2-tailed) > 0.05, then the test is not significant or H0 is accepted. In other words, there is no difference in students' attitudes towards learning mathematics through PBL between PBL-P and PBL-NP classes. So, it can be concluded that the attitude of students in PBL-P and PBL-NP groups is not different and positive towards learning mathematics through PBL. In addition, descriptively, it can also be concluded that students in PBL-P and PBL-NP classes agree with learning mathematics through PBL because the average value of student answers about attitudes is all close to 4 on the Likert scale.

Discussion

This study found that there was no significant difference between the critical thinking skills of students who studied with PBL-P and PBL-NP, but both showed an increase in critical thinking skills compared to conventional learning. This finding supports the hypothesis that PBL is generally more effective in improving critical thinking skills compared to conventional learning. However, the effect of PBL on critical thinking skills does not depend on students' initial ability.

Factors affecting the effectiveness of PBL include the lack of adjustment of PBL to students who are not accustomed to critical thinking, short experimental time, and lack of application of authentic assessment. To increase the effectiveness of PBL, the proposed alternatives include improvements in PBL design, extension of experiment time, and application of authentic assessment. Nevertheless, learning through PBL still has a positive contribution in developing students' critical thinking skills.

The contribution of learning (PBL) and initial ability to critical thinking ability shows that although PBL can accelerate the process of assimilation and accommodation, students' initial ability remains an important factor. Students with higher initial ability tended to have greater improvement in critical thinking ability. However, there was no interaction between learning factors and initial ability, suggesting that the effect of learning on critical thinking ability does not depend on the initial level of students' ability.

3. CONCLUSION

This study shows that business students who learnt with Problem-Based Learning (PBL) strategy showed better critical thinking skills than those who followed conventional learning. There was no significant difference between the critical thinking skills of students who learnt with two different types of PBL, but both were successful in improving critical thinking skills. Although there was no significant contribution from the initial ability of students learning with PBL, the positive attitude of students towards PBL learning shows the potential of PBL in improving the quality of mathematics learning in business colleges. Further development is needed in the implementation of PBL, including lecturer training, development of integrated teaching materials, and further research to involve other aspects of students' mathematical thinking competence. Future research should focus on the comprehensive development and implementation of Problem-Based Learning (PBL) in business education, particularly in mathematics. This includes providing extensive training for lecturers to effectively deliver PBL, creating integrated and contextually relevant teaching materials, and expanding the scope of research to encompass other dimensions of students' mathematical thinking competences. Additionally, investigating the long-term impact of PBL on critical thinking skills and exploring the attitudes and perceptions of students towards PBL across diverse educational contexts will be essential. This approach will ensure a more holistic understanding of PBL's effectiveness and its potential to enhance the overall quality of mathematics learning in business colleges.

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