

Improving Critical Thinking Skills Through Problem-Based Learning Model and Argumentation in Group Theory Course

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Abstract

Argumentation is one of the factors considered in measuring critical thinking skills. This study aims to evaluate the effectiveness of the Argumentation-based Problem-Based Learning model in enhancing the critical thinking skills of prospective mathematics teachers. This study used a post-test only control design involving 53 prospective mathematics teacher students at UPGRIS, consisting of two classes, namely the experimental class and the control class with a purposive sampling technique. The data collection technique was carried out through a critical thinking ability test. The data analysis technique used was a prerequisite test analyzing with a paired sample t-test hypothesis test, independent sample t-test and N-gain. The results showed that the experimental class experienced an increase in critical thinking skills in the group theory course. The critical thinking skills of the experimental class with the Problem Based Learning and Argumentation model learning were better than the control class with a sig <0.05. The increase in students' critical thinking skills increased significantly with a moderate category (N-gain = 0.47). The indicator of critical thinking skills in the criteria stating that there are problems in the information provided experienced the greatest increase, while the indicator of constructing valid arguments experienced the lowest increase. There was an increase in the ability of prospective teachers in constructing arguments but in the low criteria. The ability to construct arguments needs to be given special attention in efforts to improve critical thinking skills.

Keywords: *Critical Thinking Skills, Problem Based Learning-Argumentation, Group Theory.*

Peningkatan Kemampuan Berpikir Kritis melalui Model Pembelajaran Berbasis Masalah dan Argumentasi pada Mata Kuliah Teori Group

Abstrak

Argumentasi menjadi salah satu yang diperhatikan dalam mengukur kemampuan berpikir kritis. Penelitian ini bertujuan untuk mengukur tingkat efektifitas model Problem Based Learning berbasis Argumentasi terhadap peningkatan kemampuan berpikir kritis calon guru matematika. Penelitian ini menggunakan jenis penelitian *post-test only control design* dengan melibatkan 53 mahasiswa calon guru matematika di UPGRIS yang terdiri dari dua kelas yaitu kelas eksperimen dan kelas kontrol dengan teknik *purposive sampling*. Teknik pengumpulan data dilakukan melalui tes kemampuan berpikir kritis. Teknik analisis data yang dilakukan adalah

dengan uji prasyarat menganalisis dengan uji hipotesis *paired sampel t-test*, *independent sampel t-test* dan *N-gain*. Hasil penelitian menunjukkan kelas eksperimen mengalami peningkatan kemampuan berpikir kritis pada mata kuliah teori group. Kemampuan berpikir kritis kelas eksperimen dengan pembelajaran model Problem Based Learning dan Argumentasi lebih baik dari pada kelas kontrol dengan $\text{sig} < 0,05$. Peningkatan kemampuan berpikir kritis siswa meningkat secara signifikan dengan kategori sedang ($\text{N-gain} = 0,47$). Indikator kemampuan berpikir kritis pada kriteria menyatakan bahwa ada masalah dalam informasi yang diberikan mengalami peningkatan paling besar, sedangkan indikator penyusunan argument yang valid mengalami peningkatan yang paling rendah. Terdapat peningkatan kemampuan calon guru dalam menyusun argumentasi namun dalam kriteria rendah. Kemampuan menyusun argumentasi perlu menjadi perhatian khusus dalam upaya peningkatan kemampuan berpikir kritis.

Kata Kunci: *Kemampuan Berpikir Kritis, Problem Based Learning-Argumentasi, Teori Grup*

INTRODUCTION

Critical thinking abilities are very important abilities to equip prospective mathematics teachers who must have the ability to analyze deeply, synthesize, and evaluate abstract concepts so that they will increase their competitiveness in the academic world and the world of work. In line with several research results that say that competitiveness in the industrial era 4.0 someone to be more appreciated in the world of work and the academic world can be increased through efforts to improve critical thinking skills. (Bermingham, 2015; Kivunja, 2015; Trilling & Fadel, 2009; Zare & Othman, 2015). Critical thinking abilities are consistently included in the higher education curriculum as a list of important things behind college and career readiness (Costa, Arthur L., 2015; Costa & Kallick, 2014; Kraisuth & Panjakajornsak, 2018).

Improving critical thinking skills needs to be programmed specifically and accompanied by instructors so that they develop well because they will not develop naturally. According to the opinions of several experts who stated that critical thinking skills do not develop through a natural process, but require special treatment through a structured teaching process (Nold, 2017). Osborne (Baker et al., 2001; Rudd et al., 2000) stated that helping students to develop thinking skills in the learning process is the most important element that needs to be made the main goal in learning. Arend (Richard I. Arends, 2008) stated that critical thinking skills can be possessed by prospective teachers if they are consistently trained either through a directed discussion program or facilitated by an instructor.

The application of interactive problem-based learning models can be an alternative solution in an effort to improve critical thinking skills. One of the learning models offered is the Problem Based Learning model which is a problem-based learning model through the process of solving real problems with a discussion process. In line with several studies that reveal that PBL allows students to develop critical thinking skills through the development of logical arguments, evaluation of claims, and resolution of conceptual conflicts (Cindy & Hmelo-Silver, 2004; Jailani et al., 2017; Jiménez-Aleixandre & Erduran, 2019). Previous studies have shown that PBL can increase student engagement in the learning process and significantly improve critical thinking skills (Liu & Pásztor, 2022; Subagiyo et al., 2023; Wiono et al., 2024).

The results of the study revealed that the level of critical thinking skills of students in Indonesia is still relatively low (Hidayati & Sinaga, 2019; Syahrial et al., 2019; Tanudjaya & Doorman, 2020). This statement is reinforced by the results of PISA and TIMSS which state that the ability to solve mathematical problems in Indonesia is classified as low (Aprilia et al., 2023). In line with these conditions, the critical thinking skills of prospective teachers at UPGRIS are still relatively low, this was revealed in the results of observations and interviews which stated that many prospective teachers have difficulty in solving complex and non-routine story problems; representing problems in different forms to develop problem-solving strategies, many have difficulty due to the lack of concepts mastered to compile them. The ability to convey arguments or questions needs to be an important highlight for prospective teachers at UPGRIS because most prospective teachers will be silent without language when asked to ask or provide arguments related to the process of solving problems presented by lecturers, especially in the Group Theory course.

Several studies have attempted to explore critical thinking skills by describing them in several internal factors and have produced varying results. Personality type is a good predictor for describing students' critical thinking skills in the process of solving problems (Fitriana et al., 2018; Rosidin et al., 2019; Thadea et al., 2018). However, teachers often pay less attention to students' personalities/characteristics in optimizing thinking skills (Halder et al., 2010). Several researchers have found different results when describing critical thinking skills in terms of gender differences. Gender does not significantly affect the results of students' critical thinking skills posttest scores (Kunandar, 2014; Permani & Prabawanto, 2019; Rudd et al., 2000; Scali & Derirhan, 2011; Wahyudi et al., 2019). Different results were presented in the study by Yousefi and Mohammadi (Yousefi, 2016) stating that critical thinking and reading comprehension have

a significant correlation, but students' critical thinking does not differ significantly when viewed from gender and proficiency level. This is different from the results of the study by Shubina & Kulakli which stated that differences in gender and level of trust between teachers and students affect the development of critical and creative thinking quality (Shubina & Kulakli, 2019). Male students have better critical thinking and problem-solving skills (Rodzalan & Saat, 2015). The mathematical critical thinking skills of female students who use the Knisley mathematical model are higher than those of male students (Sari & Nurfauziah, 2019).

Several studies have tried to explore the use of problem-based learning models and learning media to improve critical thinking skills. The application of the inquiry model has a positive effect and can improve critical thinking skills (Rahmi et al., 2019; Sabur et al., 2023; Wale & Bishaw, 2020). The use of Augmented Reality-based learning media is effective in improving critical thinking skills (Zuniari et al., 2022). The Problem-Based Learning model is effective in improving critical thinking skills in learning in Malaysia (Zabit, 2010). The PBL model is effective for critical thinking skills in mathematics learning (Aini et al., 2019). The problem-posing learning model is effective in improving critical thinking skills (Agoestanto et al., 2019; Permanawati et al., 2018). Argumentation fluency has a significant effect on critical thinking skills (Hashemi et al., 2014; Lazarou et al., 2017). Based on the description of the studies above, it can be stated that there are still few/no studies that apply the problem-based learning model by considering problems in everyday life and argumentation skills to improve critical thinking skills. The purpose of this study is to determine the level of effectiveness of the Argumentation-based PBL learning model in an effort to improve critical thinking skills.

RESEARCH METHODS

This study uses a quasi-experimental research type involving 53 prospective mathematics teacher students at the Republic of Indonesia Teachers Association University (UPGRIS) consisting of two classes, namely the experimental class and the control class with a purposive sampling technique in the Group Theory course with purposive sampling technique. Data collection techniques are carried out through critical thinking ability tests. Data analysis techniques used are prerequisite tests analyzing with hypothesis tests with paired sample t-tests, independent sample t-test

and N-gain in the experimental class. Data processing using Statistical Package for Social Science (SPSS) for Windows software with a significance level of 5%. To determine the average significant difference in the improvement of problem-solving skills in the experimental group, prerequisite tests, including normality and homogeneity tests, were conducted on both the pretest and posttest results before performing the hypothesis test. This research is an experimental research, where there are control and experimental classes selected with the principle of convenience sampling. While the method used is post-test only control design. The experimental class was treated with Problem basic learning and argument in the learning process which is reflected in the learning tools developed by the researcher, while the control class learning is carried out as usual or depending on the Learning Implementation Plan (RPP) that has been made previously.

This test is given to students before and after learning. The data obtained in this study are quantitative in the form of normalized gain scores (Archambault, 2008) using the formula $N-Gain = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}}$. With the N-gain value criteria presented in Table 1 below.

Table 1. N-Gain Criterion

Limitation	Category
$N-gain > 0,700$	High
$0,30 \leq N-gain \leq 0,70$	Sedang
$N-gain < 0,30$	Rendah

Indicators of critical thinking skills were developed from the Ennis and steps of Jhon Dewey's problem solving. The following table shows indicators of critical thinking skills in solving problems.

The research instrument used was a critical thinking ability test. This test was designed based on modified critical thinking indicators by considering the main elements of critical thinking ability proposed by Ennis, known as Frisco (Focus, Reason, Inference, Saturation, Clarity, Review) (Cahyono et al., 2023; Ennis, 1993; Mason, 2007) by considering the problem-solving stages proposed by John Dewey (Cahyono et al., 2022; Rich, 1985) and the stages of a person in generating/delivering valid arguments. The analysis of the decline in critical thinking ability indicators is described in Table 2 below;

Table 2. Indicators of critical thinking skills are developed by paying attention to the argumentation component in solving problems

No	Elements of Critical Thinking	Problem Solving Steps According to John Dewey	Indicator of critical thinking
1	Focus	Recognizing the problem (confronting the problem) Define the problem (diagnose or define problem)	a. Digging for information to support the formulation of arguments; IBK-1. Stating that there is a problem in the information provided IBK-2. Interpreting information through activities of stating/writing/selecting all important information provided and supporting the problem-solving process clearly and completely
2	Reason	Finding solutions (inventory several solutions) or Developing several hypotheses: a hypothesis is an alternative solution to solving a problem	b. Developing valid arguments through activities: IBK-3. Organizing/revealing previously learned definitions, axioms or formulas related to the problem (finding patterns (sketches)). formulating problems in the form of variables, modeling problems in algebraic equations) IBK-4. Using previously learned definitions, axioms or formulas to develop several alternative problem solving strategies accompanied by arguments.
3.	Inference	Testing some ideas (conjecture consequences of solutions)	c. Testing the validity of arguments through activities: IBK-5. Determining one assumption/hypothesis from several hypotheses/assumptions as an alternative solution to the right problem so as to be able to predict the allocation of time needed to solve the problem. IBK-6. Implementing a plan to solve a math problem correctly
4.	Situation	Taking the best hypothesis (test consequences)	d. Evaluating arguments through activities: IBK-7. Concluding from the process to determine the most appropriate solution.
5.	Clarity	Checking proven hypotheses	e. Rechecking the arguments that have been given IBK-8. Ensuring the correctness of the answers written through valid logic IBK-9. Conduct a thorough recheck so that you can compile arguments that are
6.	Overview		

based on valid logic for each conclusion that is correctly determined.

RESULTS AND DISCUSSION

The improvement of students' critical thinking skills can be seen by analyzing the critical thinking skills test scores both before and after learning, first tested for normality. The results of the critical thinking ability test after the pretest and posttest are shown in Table 3. The following are the average results of the pretest and posttest of the critical thinking ability of prospective teacher students.

Table 3. Recapitulation of Critical Thinking Ability Test Scores for the Experimental Class and Control Class

No	Description	Control Class		Experimental class	
		Pretest Score	Posttest Score	Pretest Score	Posttest Score
1	Average Score	35,21	52,35	42,58	83,96
2	Smallest score	30	40	35	45
3	Highest Score	45	65	55	90
4	Score Range	15	25	20	40
5	Standard Deviation	6,21	10,15	7,28	17,05

Table 3 reveals that the average critical thinking skills of both the experimental and control classes increased. The average increase in critical thinking scores in the experimental class was higher than in the control class, indicating that the argumentation-based PBL model provides positive support for improving critical thinking skills. Problem-based learning models with argumentation scaffolding provide significant support for the critical thinking skills of prospective teachers in terms of gender differences and personality types (Cahyono et al., 2021; Jumadi et al., 2021).

Table 4. hasil Uji Normalitas

Tests of Normality							
Kelas		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Hasil	Pretest Kelas Kontrol	.301	24	.057	.795	24	.081

Posttest Kelas Kontrol	.273	24	.149	.824	24	.059
Pretest Kelas Eksperimen	.250	29	.221	.827	29	.228
Posttest Kelas Eksperimen	.341	29	.224	.583	29	.172

Based on table 4, In the Kolmogorov Smirnov normality test criteria table in table 2, if $\text{sig} > 0.05$ then the data is normally distributed. Based on the normality test of the control class pretest data, $\text{sig} = 0.057$ or $\text{sig} > 0.05$ was obtained and for the control class pretest data, $\text{sig} = 0.149$ or $\text{sig} > 0.05$, then both pretest data were normally distributed. While for the control class posttest data, $\text{sig} = 0.221$ or $\text{sig} > 0.05$ was obtained and for the experimental class posttest data, $\text{sig} = 0.224$ or $\text{sig} > 0.05$, then both posttest data were normally distributed. For the next test is the homogeneity test. Table 5 is a data homogeneity test.

Table 5. Test of Homogeneity of Variance.

Test of Homogeneity of Variance				
	Levene Statistic	df1	df2	Sig.
Based on Mean	.041	1	51	.840

Dari hasil uji tersebut didapatkan signifikansi sebesar $0,840 > 0,005$

Based on the results of the homogeneity test, a significance value of 0.840 was obtained, which is greater than the significance level of 0.05. This indicates that there is no significant difference in variance between the groups tested. Thus, it can be concluded that the data has homogeneous variance. In experimental research, classes must be homogeneous and normal to ensure that research results are accurate and not influenced by other uncontrolled factors (Fraenkel & Wallen, 2008; Sugiyono, 2019). Class homogeneity can be tested using the homogeneity of variance test, while data normality can be tested using normality tests such as the Kolmogorov-Smirnov test or the Shapiro-Wilk test (Field, 2013).

Furthermore, the researcher conducted a paired sample t-test using SPSS to determine the increase in critical thinking skills of prospective teachers after receiving

learning treatment with the Problem Based Learning and Argumentation models in the group theory course in the experimental class. Below are the results of the paired sample t-test using SPSS.

Tabel 6. Hasil *Paired sample t test*

Paired Samples Test									
		Paired Differences					Significance		
		Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference		t	df	Two-Sided p
					Lower	Upper			
Pair 1	Pre Test - Post Test	-41.37931	9.24822	1.71735	-44.89714	-37.86148	-24.095	28	<,001

Table 6 shows that the experimental class experienced an increase in the critical thinking skills of prospective teachers after receiving learning treatment with the Problem-Based Learning and argumentation models in the Group Theory course, as indicated by the results of the Paired sample t-test with a significance value of 0.001, which is smaller than 0.05. There was a very significant difference between the pre-test and post-test scores, namely an increase in the average score of 41.38 points, which indicates that the application of the model is effective in improving students' critical thinking skills. In line with several studies which reveal that the application of problem-based learning models by adding arguments effectively improves the critical thinking skills of junior high school students (Akhdinirwanto et al., 2020; Farisi et al., 2023). The average N-Gain is 0.39 so that the category of increasing students' critical thinking skills is included in the moderate category. In accordance with Fadilah's research (Fadilah et al., 2024) which states that one of the factors that causes an increase in students' critical thinking skills is due to an increase in students' ability to convey arguments. Students' critical thinking skills can be improved through fun learning with a problem-based learning model with argumentation nuances (Ariyanto et al., 2020; Farisi et al., 2023). The problem-based learning process with direct self-observation trains students to be able to argue and increases the development of students' thinking skills (Demircioglu et al., 2023; Rusmini et al., 2021).

The next step is to conduct an Independent Sample T-Test to determine whether there is a difference in the critical thinking abilities of the experimental class using the Problem Based Learning and Argumentation learning model with the control class. Table

7 is Independent-Sample t-Test.

Tabel 7. Hasil Independent Samples Test

		Independent Samples Test			
		t-test for Equality of Means			
		Significance			
		t	df	Two-Sided p	Mean Difference
Hasil Kemampuan berpikir kritis	Equal variances assumed	-22.692	56	<,001	-41.37931
	Equal variances not assumed	-22.692	43.626	<,001	-41.37931

Problem-based learning models with argumentation optimize the improvement of all indicators of students' critical thinking abilities. Indicators of improvement of each indicator of critical thinking ability are reviewed from the increase in scores obtained by students, from the initial test score to the final test score, and the normalized score. The increase in the average score of the initial test and the final test of critical thinking ability for each indicator is presented in Figure 1 and 2.

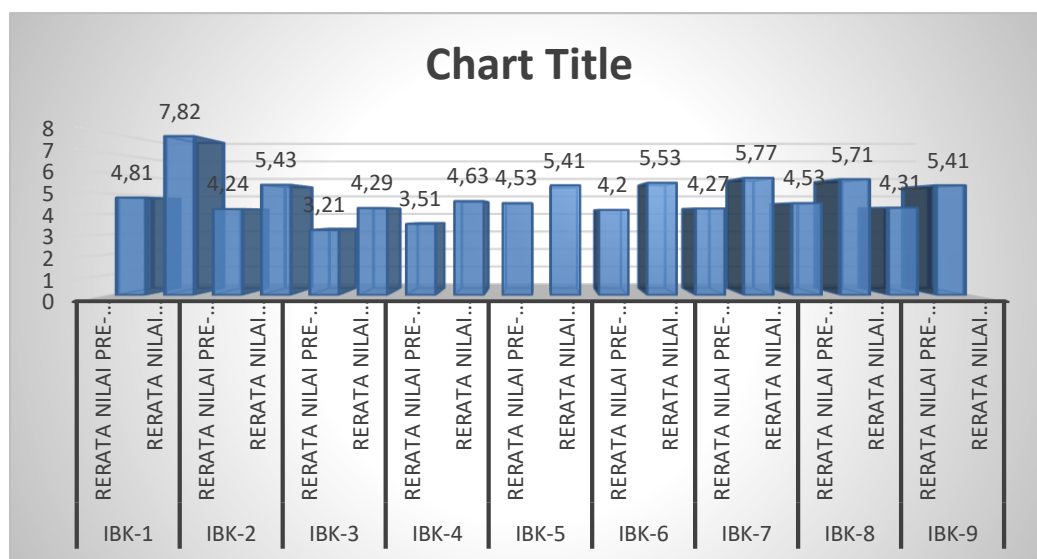


Figure 1. Average pre-test and post-test scores for each indicator

The increase of each indicator is seen in the N-gain test of each indicator. The following figure is the N-gain of each indicator.

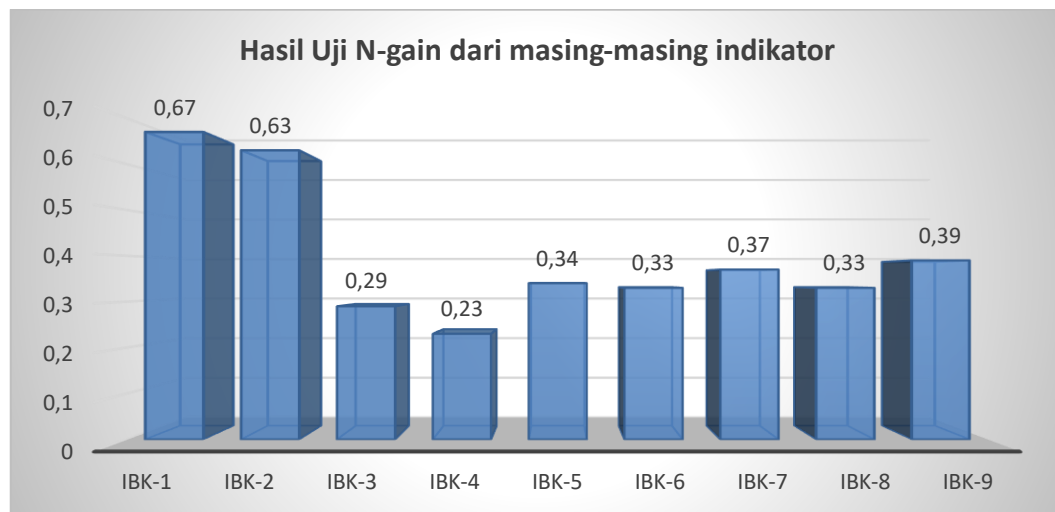


Figure 2. N-gain test results for each indicator

From Figure 1 and 2 it is obtained that the table shows the highest average increase occurred in IBK-1 (stating that there is a problem in the information provided), namely, the pre-test of 4.81 to 7.82. IBK-4 is an indicator of critical thinking skills that experienced the lowest score increase. Figure 3 we get the information that the results of N-gain show that in IBK 1 it is included in the medium category while in IBK 1 it is 0.67 in the High category while in IBK-3 and IBK-4 are in the low category. The Z test on each indicator shows whether there is a difference in the average test of the initial and final test scores for each indicator of critical thinking ability. As stated by (Cahyono et al., 2022; Pertiwi et al., 2019) that there is a relationship between argumentation skills and problem-solving skills. In the learning process, the development of critical thinking involves students more as thinkers than as learners (Hasnunidah et al., 2020; Jumadi et al., 2021; Rosidin et al., 2019).

CONCLUSION

Based on the findings of this study, the significant difference in increasing critical thinking skills is supported by the results of the average difference test with Z table 1.64 and Z count = 11.53 so that it can be concluded that students' critical thinking skills before and after learning are significantly different or the final test score (posttest) of students after learning has increased significantly compared to before learning. The average N-Gain is 0.39 so that the category of increasing students' critical thinking skills is included in the moderate category. the average critical thinking ability of the experimental class

was 73.21, higher than that of the control class at 52.35. Based on the results of the t-test, the calculated $t_{hitung} 2.021 > 2.003 t_{Table}$, so it can be concluded that the critical thinking skills of the experimental class that received the problem-based learning-argumentation model treatment were better than the control class.

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