RESEARCH ARTICLE

PBL with the brainstorming method: Can it influence students' critical and creative thinking ability?

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Abstract: The ability to think critically and creatively is a capability that must be possessed by student in this century. This ability is needed to adjust to changes, it takes habit in bringing up new ideas to solve various problems that occur. This study aims to determine the effect of the Problem-Based Learning (PBL) model with the brainstorming method on students' critical and creative thinking abilities. The research method uses quasi-experimental research with a non-equivalent pretest-post-test control group design. The population of this study was class X MIPA students at SMA Negeri 1 Kota Tangerang Selatan for the 2022/2023 academic year. Sampling using a simple random sampling technique, and obtained as many as 80 students. Data on critical and creative thinking ability were obtained through essay tests. Data were analyzed using the MANOVA test. Prerequisite test results obtained data normally distributed and homogeneous. Based on the results of the MANOVA hypothesis test ($p < 0.05$), shows that the treatment of PBL with the brainstorming method influences critical and creative thinking ability with a significance value of 0.000 and 0.008, respectively. The PBL model with the brainstorming method can be used by teachers to improve student's critical and creative thinking ability.

Keywords: creative thinking; critical thinking; environmental changing; problem-based learning

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Article history:
Received: 11 August 2023
Revised: 17 October 2023
Accepted: 17 October 2023
Published: 23 October 2023

10.22219/jpbi.v9i3.28551

p-ISSN: 2442-3750
e-ISSN: 2537-6204

How to cite:
Praminingsih, I., Miarsyah, M., & Kurniati, T. H.. (2023). PBL with the brainstorming method: Can it influence students' critical and creative thinking ability? *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(3), 346-358. https://doi.org/10.22219/jpbi.v9i3.28551

Introduction

Today, the ability to think critically is one of the abilities that must be possessed by all students (Chalkiadaki, 2018; Saleh, 2019). The ability to think critically is one of the most important basic assets and is part of human maturity (Mahanal, 2012). Critical thinking is important due to this skill have an essential rule in making decisions and providing solutions to a problem (Alsaleh, 2020; Dwyer et al., 2014). However, Indonesia is still classified as a country that has not been able to create students' ability to think critically in dealing with the problems and demands of the times (OECD, 2018). Based on data from the OECD (2015), only 0.8% of students in Indonesia could solve high-level thinking questions, which in this case think critically, therefore Indonesia is still ranked in the bottom 10, namely ranking 62 out of 70 countries.

In addition to critical thinking ability, there are creative thinking ability that need to be improved by students (Alismail & McGuire, 2015; Geisinger, 2016). Creative thinking related to the ability to develop unusual, quality ideas, and be able to redefine a problem effectively and think deeply (Ramalingam et al., 2020). However, based on the results of a study from TIMMS & PIRLS (2015), which tested creative thinking questions, it showed that students' creative thinking abilities in Indonesia tended to be lacking. Indonesia is in the bottom four positions out of a total of 48 participating countries.

The low critical and creative thinking ability of students in Indonesia are caused by learning activities that have not implemented evaluations to measure critical thinking ability (Rahayuni, 2016). Learners find it difficult to communicate and relate their knowledge and lack of high-level thinking, such as critical and creative thinking, especially in the field of Biology (Putri et al., 2014). Related to science topics, the

concept of material from biology lessons is closely related to everyday life such as the concept of environmental change (OECD, 2015). The concept of environmental change is considered important to teach so that students have an awareness from an early age to preserve the environment and requires students to think critically in solving environmental problems and the impacts caused (Margareta & Purnomo, 2018). The concept of environmental change also requires students to analyze the causes and impacts on life so that students can propose ideas or ideas as solutions to existing problems. Thus, learners' critical and creative thinking skills are more honed.

What the teacher needs to do is to formulate an appropriate learning model or method. The solution that is seen as capable of overcoming these problems and being able to train critical and creative thinking ability is the Problem-Based Learning (PBL) model. This model is proven to improve students' critical thinking ability (Fadilla et al., 2021; Maulidiya & Nurlaelah, 2019). In addition to the PBL model which can support students to have critical and creative thinking knowledge, a method is needed for students to provide ideas in solving problems. The learning method that is oriented towards the development of thinking ability in problem solving is the brainstorming method (Al-Khatib, 2012). The brainstorming method is proven to develop critical and creative thinking ability, because through the ideas put forward, it will train students in finding information and analyzing arguments (Aldeirre et al., 2018). Thus, this learning method prioritizes the activeness of students to develop the potential that exists in students to the fullest and facilitate the understanding and absorption of students in biology subjects, which contributes to increasing students' critical and creative thinking activities and abilities.

In line with its potential to empower critical and creative thinking skills, numerous studies have examined the impact of PBL on enhancing both critical (Fadilla et al., 2021; Hussin et al., 2018; Maulidiya & Nurlaelah, 2019) and creative thinking skills (Ahmad et al., 2020; Birgili, 2015; Khoiriyah & Husamah, 2018). Few other studies have also integrated PBL with brainstorming (Fatmawati & Wulandari, 2020; Purwanti et al., 2020). However, research that integrates PBL with brainstorming methods and analyzes its influence on both high school students' critical and creative thinking skills on biology subject remains scarce. Therefore, the objective of this research is to analyze the impact of the PBL model with brainstorming methods on both of these thinking skills.

Method

Research design

This research is quasi-experimental research. This research design is nonequivalent control groups design. This research was divided into two groups, namely PBL model with concept mapping method as the control group and PBL with brainstorming method as the experimental group. The research design can be explained in Table 1.

Table 1. Research design

Groups	Pre-Test	Treatment	Post Test
Experimental	O_1	X_1	O_2
Control	O_3	X_2	O_4

Note:

O_1 : Pre-test for the experimental class (PBL with the Brainstorming method)
O_3 : Pre-test for the control class (PBL with the Concept Mapping method)
X_1 : Treatment of PBL with the Brainstorming method given to the experimental class
X_2 : Treatment of PBL with the Concept Mapping method given to the control class
O_2 : Post-test for the experimental class (PBL with the Brainstorming method)
O_4 : Post-test for the control class (PBL with the Concept Mapping method)

Population and samples

The selection of the sample and population was carried out using a multi-stage random sampling technique with the following stages: 1) Determination of the population using a purposive sampling technique. The population of this study was 247 students in class X MIPA, SMA Negeri 1 Kota Tangerang Selatan, in the even semester of the 2022/2023 academic year. 2) The cluster random sampling technique is used in determining the experimental class and control class of many as 2 classes. The number of students in each class was 44, so the total number of students who were used as respondents was 88 students. 3) Determination of the research sample using a simple random sampling technique. The research sample was obtained from many as 80 students randomly.

Research procedure

This research procedure consists of three stages, including: 1) The preliminary stage consists of identifying problems to the intended school and preparing a lesson plan on the concept of material,

compiling learning devices (Lesson Plan, Student Worksheets, and assessment instruments). After the instrument is made, then a trial is conducted to 30 students, the instrument is analyzed based on validity and reliability. 2) The implementation stage begins with determining two sample groups that will be the control and experimental groups, procuring pretests in both groups, conducting research using the PBL model with the brainstorming method in the experimental class and PBL with the concept mapping method in the control class, procuring posttests in both research groups, calculating N-Gain, testing prerequisite analysis, and MANOVA (Multivariate Analysis of Variance) hypothesis testing. 3) The final stage of this research is drawing conclusions from the research results.

Data sources and Research instruments

Critical Thinking Ability Test Instrument, compiled based on indicators according to Facione (2015) with indicators 1) Interpretation, 2) Inference, 3) Analysis, 4) Evaluation, 5) Explanation and 6) Self-regulation. The validity of the critical thinking ability items was tested using Pearson Product Moment, there was 1 item that was invalid. Instrument reliability was calculated using the Alpha Cronbach formula, the reliability coefficient of the instrument for assessing critical thinking ability was 0.855 (very high). Creative Thinking Ability Test Instrument, compiled based on indicators according to Torrance (1984), namely fluency, flexibility, originality, and elaboration. The validity of the items on the ability to think creatively will be tested using Pearson Product Moment, there are 3 questions that are invalid. Instrument reliability was calculated using the Alpha Cronbach formula, the reliability coefficient of the instrument for assessing creative thinking ability was 0.725 (high). Non-test instruments in the form of student worksheets and observation sheets. Sources of data in this study can be seen in Table 2.

Table 2. Data sources in this study

Test/Non-test	Data Type	Data Sources	Data Collection Technique
Test	*Pretest*	Students in the experimental and control class	objective test
Non-test	Assessment on the process of giving treatment	Students in the experimental and control class	Student Worksheets *Problem Based Learning* with the *brainstorming method*
		Students in the experimental and control class	student worksheets Problem Based Learning with the concept mapping method
	Learning implementation assessment	Students	observation sheet
Test	*Posttest*	Students in the experimental and control class	objective test

Data Analyses

The entire processing uses SPSS software version 25. The prerequisite test is the normality test and homogeneity test. The normality test used is the Kolmogorov-Smirnov test. The homogeneity test in this study consisted of two steps, namely the variance homogeneity test using Levene's Test and the covariance matrix using Box's Test. Hypothesis testing in this study used the MANOVA (Multivariate Analysis of Variance) test with Pilae Trace, Wilk Lambda, Hoteling Trace, and Roy's Largest Root analysis at a significance of 0.05. N-Gain analysis. This is done to determine the increase in students' critical and creative thinking ability obtained after learning activities.

Results and Discussion

The average value of students' critical thinking ability was 45.09 for the pretest and 83.43 for the posttest while in the control class, the average pretest score was 37.54 and the posttest was 78.57 (Figure 1). Based on the data, it shows that the students' critical thinking ability in the experimental class is greater than in the control class. The difference in value between the pretest and posttest in the experimental class was 38.34 and, in the control, class was 41.03.

Furthermore, the percentage of results per indicator of critical thinking of students in the pretest-posttest experimental class shows that the highest value of critical thinking ability in the experimental class during the pretest is the self-regulation indicator, which is 49.38%, while the lowest value is in the explanation indicator of 42.29% (Figure 2). At the time of the posttest, the highest value was the interpretation

indicator of 85.21%, while the lowest value was the explanation indicator of 81.46%. This shows that there is an increase in critical thinking ability after being given the treatment of the PBL model with the brainstorming method.

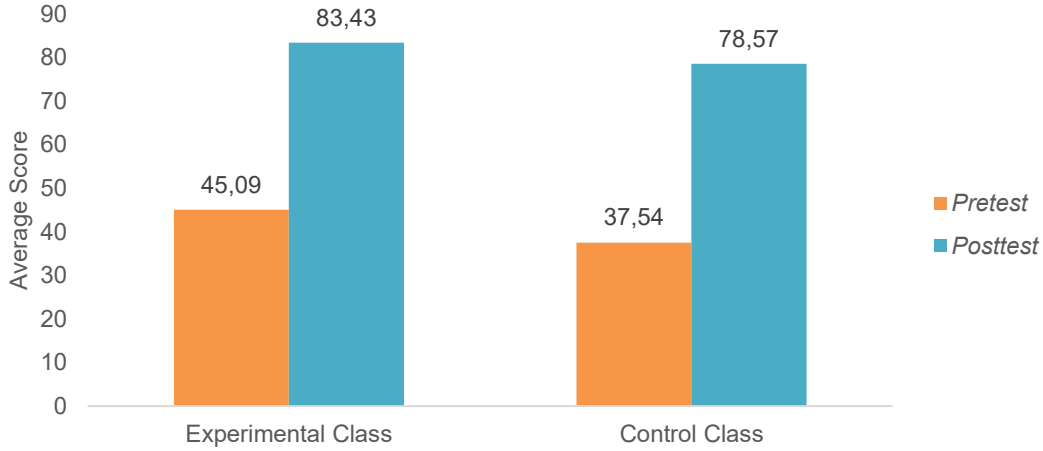

Figure 1. Comparison of average results for critical thinking ability

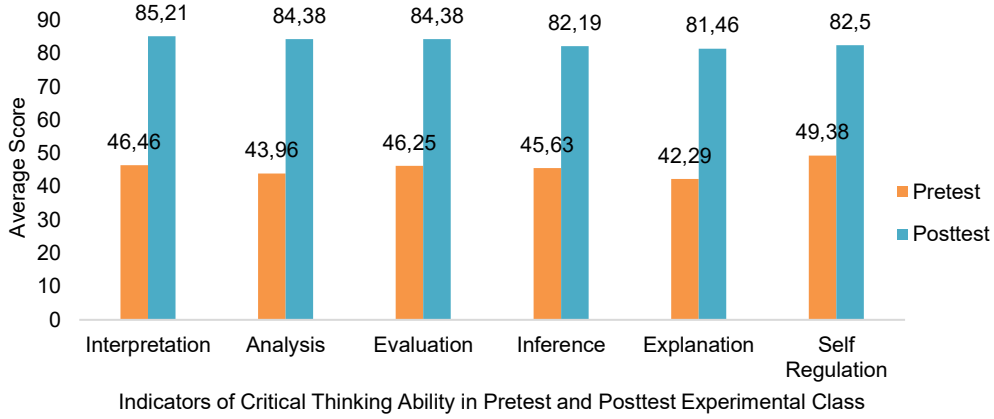

Figure 2. Percentage of results indicators of critical thinking ability of experimental class students

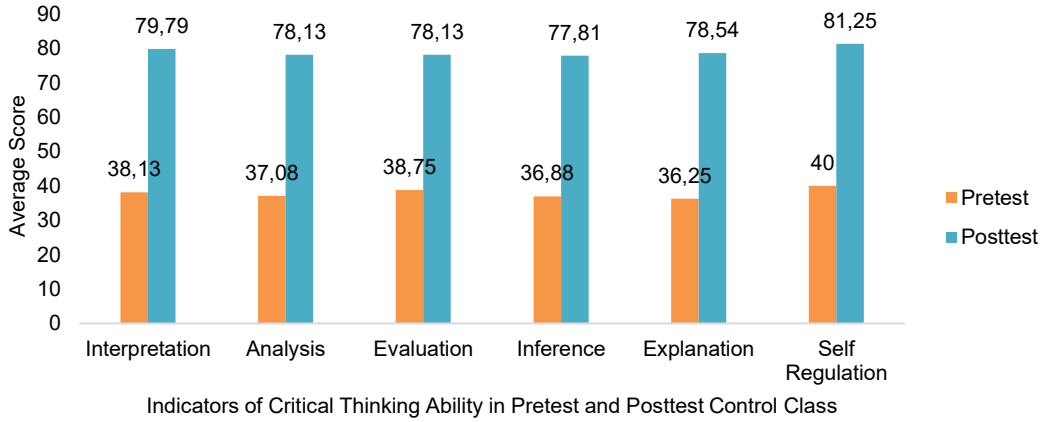

Figure 3. Percentage of results indicators of critical thinking ability of control class

Then, in the control class, the highest indicator in the control class at the pretest was self-regulation which is equal to 40%, while the lowest value was the explanation indicator of 36.25% (Figure 3). During the posttest, the highest score was the self-regulation indicator of 81.25%, while the lowest score was

the inference indicator of 77.81%.

Table 3. N-gain calculation results of critical thinking ability

Normal Gain	Experiment	Control
highest score	0.89	0.85
lowest score	0.60	0.62
average	0.75	0.73
category	High	High

Moreover, based on Table 3, the average N-Gain calculation of critical thinking ability in both classes has a high category. The average experimental class was 0.75 while the control class has an average of 0.73. This shows that the increase in students' critical thinking ability in the experimental class is higher than the control class.

Table 4. Critical thinking ability data normality test results

Statistics	Pretest		Posttest	
	Experiment	*Control*	*Experiment*	*Control*
Sample (n)	40	40	40	40
Sig	0.200	0.200	0.076	0.130
Conclusion	Normal	Normal	Normal	Normal

Furthermore, critical thinking ability data were normally distributed (Table 4) and the variance was homogen (Table 5). Then, based on univariate analysis, the PBL model with the brainstorming method has a significant effect on the critical thinking ability (Table 6).

Table 5. Variance homogeneity test results

Levene Statistic	df_1	df_2	Sig
0.072	1	78	0.789

Table 6. Univariate significance test results

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Critical Thinking	465.613[a]	1	465.613	13.969	.000
	Creative Thinking	262.812[b]	1	262.812	7.403	.008

The lowest percentage of pretest and post-test results indicator of critical thinking ability in the experimental class and the control class was the lowest in the explanation indicator. Students are less able to explain statements and opinions that have been expressed, it is feared that students will care less about the environment, due to a lack of insight into environmental problems. This shows that students are still lacking in explaining strong statements or opinions regarding environmental change issues. Low explanation indicators can occur because students are still weak in developing correct explanations (Maslakhatunni'mah et al., 2019). This can happen because students still depend on the teacher in the learning process, so they are still lacking in developing what these students understand. This is similar to the research of Hayudiyani et al., (2017) that in explanation indicators can be influenced by students who are unable to write down the final results, explain and give reasons for the conclusions drawn logically and make sense so that this can affect their ability think students.

The results of the N-gain analysis of critical thinking ability obtained in the experimental class and control class showed that the increase in students' critical thinking ability in the experimental class was higher and categorized as high compared to the control class. The experimental class that used the PBL model with the brainstorming method, the learning was centered on students such as developing ideas, finding solutions to problems, and besides that students could convey their ideas openly. These results are like the research of Purwanti et al., (2020), which states that it will be effective if PBL is combined with the brainstorming method, because the activity of collecting ideas about a problem can affect the problem-solving process which can train students' ability to think critically. Unin and Bearing (2016) also argued that, through the brainstorming method, the approach in learning is centered on students such as conveying ideas, finding solutions, and students' openness to their knowledge can affect critical thinking ability. Thus, it can be said that learning that applies the PBL model with the brainstorming method is effective in improving critical thinking ability.

In the application of the PBL model using the brainstorming method, the learning process places more emphasis on problem solving and being active in conveying ideas that can initiate critical thinking. Guerra and Holgaard (2016) argues that the PBL model is influential in increasing critical thinking ability because learning based on a problem will emphasize processes and create an independent, collaborative, and group-based learning environment. PBL uses constructivist principles to encourage application of prior knowledge, collaborative learning, and active engagement of learners (Zhou, 2018). Florea and Hurjui (2015) also argued that PBL can initiate critical thinking, because PBL can update knowledge to make

learning experiences, identify causal relationships, and evaluate information. Sinprakob and Songkram (2015) also stated that this PBL model can provide a meaningful learning experience for students, because it goes through a complex series of problem solving (Hu et al., 2018). In the application of PBL which is integrated with brainstorming, students are given the opportunity to express their opinions through critical thinking regarding the problems encountered (Miller, 2009). So, it can be said that the PBL model with the brainstorming method can influence the improvement of students' critical thinking ability.

Furthermore, the average value of the students' creative thinking ability in the experimental class is greater than the control class (Figure 4). Moreover, the percentage of students' creative thinking indicator results in the pretest-posttest experimental class shows that the highest creative thinking ability score in the experimental class during the pretest is the elaboration indicator, which is 53.44%, while the lowest score is the fluency indicator, which is 51.88 %. During the posttest, the highest score for students' creative thinking ability was the originality indicator of 84.17%, while the lowest score was the fluency indicator of 83.33% (Figure 5). This indicates that there is an increase in the ability to think creatively after being treated with the PBL model with the brainstorming method.

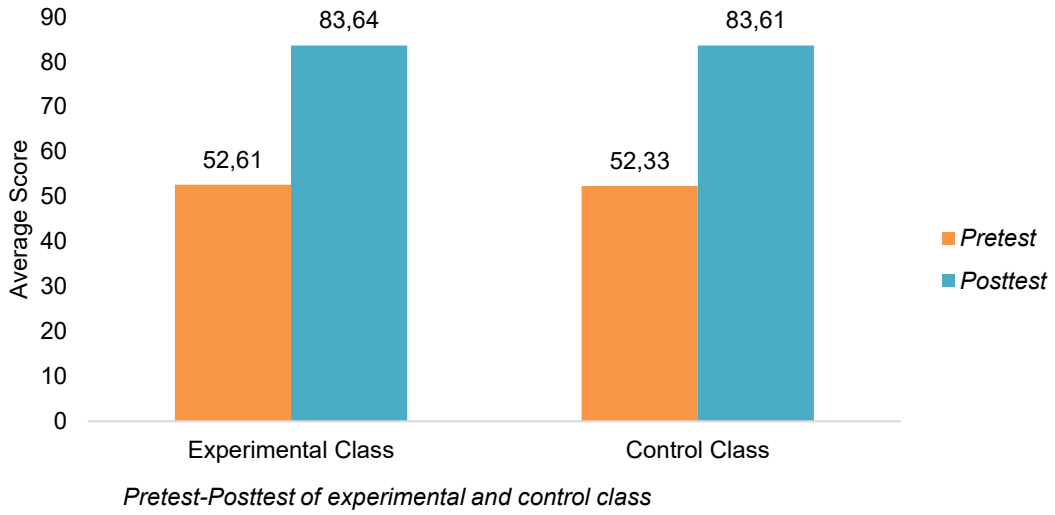

Figure 4. Comparison of average results for creative thinking ability

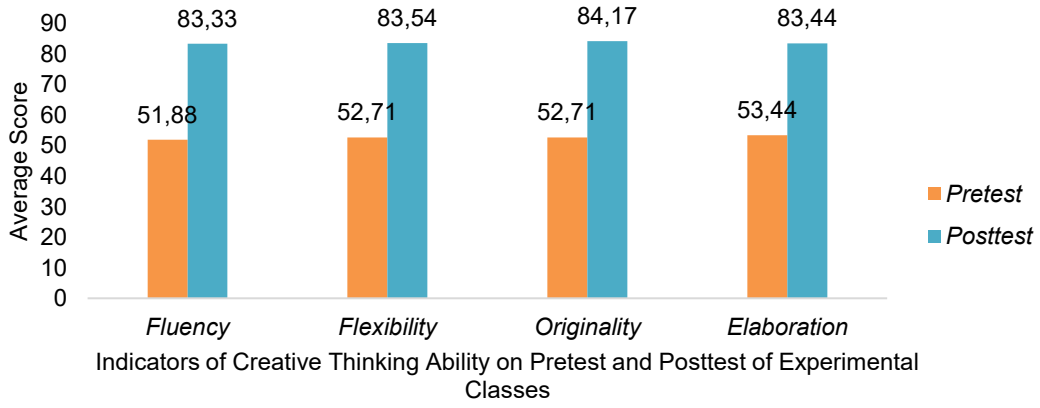

Figure 5. Percentage of results indicators of creative thinking ability of experimental class students

The percentage of students' creative thinking indicator results in the pretest-posttest control class shows that the highest creative thinking ability score in the control class during the pretest is an originality indicator that is equal to 53.54%, while the lowest value is that of a fluency indicator of 51.25 % (Figure 6). At the time of the posttest, the highest score of students' creative thinking ability was on the flexibility indicator of 84.17% while the lowest score was on the elaboration indicator of 77.81%.

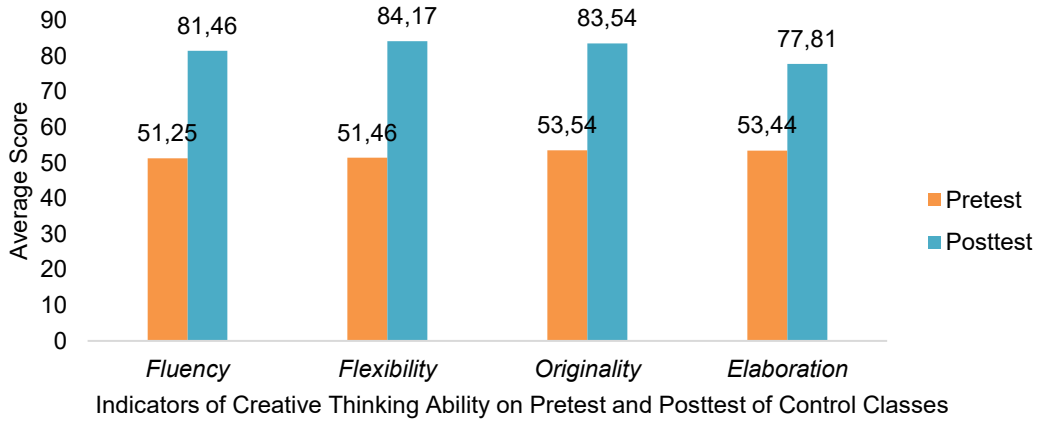

Figure 6. Percentage of results indicators of creative thinking ability of control class

Based on Table 7, the average N-Gain calculation of creative thinking ability in both classes has a high category. The average experimental class is 0.74, while the control class has an average of 0.72. This shows that the increase in students' creative thinking ability in the experimental class is higher than the control class. Then, based on Table 8, the results of the normality test show that both classes are normally distributed, both for pretest and posttest results to measure students' critical thinking ability. The data also has a homogeny of the variance (Table 9). Then, based on univariate analysis, there *was* an effect of the PBL model with the brainstorming method on the creative thinking ability of students on environmental change material (Table 10).

Table 7. N-Gain calculation results of creative thinking ability

Normal Gain	Experiment	Control
highest score	0.94	0.88
lowest score	0.54	0.56
average	0.74	0.72
category	High	High

Table 8. Creative thinking ability data normality test results

Statistics		Pretest		Posttest	
		Experiment	*Control*	*Experiment*	*Control*
	Sample (n)	40	40	40	40
Sig		0,053	0,064	0,200	0,200
	Conclusion	Normal	Normal	Normal	Normal

Table 9. Variance homogeneity test results

Levene Statistic	df_1	df_2	Sig
0.022	1	78	0.881

Table 10. Univariate significance test results

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Critical Thinking	465.613[a]	1	465.613	13.969	.000
	Creative Thinking	262.812[b]	1	262.812	7.403	.008

The results of the research on creative thinking ability both on the pretest and posttest, showed that the highest average scores were obtained in the experimental class compared to the control class. This can occur because in the learning process using PBL with the brainstorming method, students are trained to express as many opinions as possible to solve a problem, and this will trigger students' creative ideas. Dewi and Riandi (2016), suggested that PBL with brainstorming will optimize the potential of both sides of the brain so as to form a new knowledge and generate creative ideas in solving problems. Similar research also stated that the results shown at the end of the learning process with PBL, students can identify and solve problems with their own abilities and develop creative thinking (Cheung, 2011).
The highest percentage of pretest and posttest results per-indicator of creative thinking ability of experimental and control classes, namely in the elaboration and originality indicators. The lowest percentage was obtained in the fluency indicator. This shows that experimental class students have been able to explain coherently and generate new ideas in different ways related to environmental change

problems, but are still lacking in building ideas that can provide solutions to environmental change problems. This can occur due to internal and external factors (Winiarsih et al., 2021). For this reason, teachers can familiarize students to be active in expressing ideas in finding solutions to problems in the learning process with the PBL model integrated with the brainstorming method.

The results of the N-gain analysis of creative thinking ability obtained in the experimental and control classes show that the increase in students' creative thinking ability in the experimental class is higher than the control class. The treatment of PBL model with brainstorming method, trains students to actively express their ideas in solving problems. The application of PBL with the brainstorming method emphasizes the activeness of students in expressing their ideas, which will certainly develop creative thinking ability. In line with this statement, Turkmen and Sertkahya (2015) stated that students who are active in developing their ideas, as well as teachers who want to continue to accept and be open to updating ideas are the main keys to an effective learning process and have a good impact on students' creative thinking. So, it can be said that the experimental class applied using the PBL model with the brainstorming method is effective in improving creative thinking ability.

Testing the second hypothesis is the influence of the PBL model with the brainstorming method on students' creative thinking abilities, which is done by using the MANOVA test. The application of PBL with the brainstorming method, students actively identify problems, find solutions to problems by expressing their opinions, and evaluate ideas that can be used as a solution to problems. Similar research shows that the results shown at the end of learning with PBL use the brainstorming method, students can identify and solve problems with their own ideas and abilities and develop their creative thinking (AlMutairi, 2015; Cheung, 2011). Learning that applies PBL makes students involved in developing creative thinking through brainstorming when hypothesizing and creating new ways of learning to be more effective (Ersoy & Başer, 2014). This brainstorming method makes the discussion process increase, student performance becomes more active and of course students become more proficient in creative thinking (Martin & Schwartz, 2014; Tsai et al., 2020). The ability to think creatively is very important for all students, because it is the basis for students' ability to determine problem-solving strategies and transform ideas (Khoiriyah & Husamah, 2018). In efforts to improve creative thinking ability, of course, teachers must motivate students by asking questions and guiding investigations to monitor the problem-solving process (Chiang & Lee, 2016; Kassab et al., 2017). The same thing was said by Strobel and Barneveld (2009), teachers must take part in implementing the PBL model with the brainstorming method, in order to make learning more meaningful and students' creative thinking abilities can increase.

Testing the homogeneity of the covariance matrix of data on the ability to think critically and creatively is a requirement for testing the MANOVA hypothesis. The results show that the value of the Box's M test = 3.196 with a Sig value of 0.375 > 0.05 (Table 11). This means that the variance/covariance matrix of the dependent variable is homogeneous. So that MANOVA analysis can be continued.

Table 11. Box's M test results data on students' critical and creative thinking ability

Parameter	Value
Box's M	3.196
Sig.	.375

Multivariate significance test to determine differences between two or more groups that can be evaluated with various statistical test criteria. The statistical tests used were Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root tests contained in the Multivariate Test table. The following results of the multivariate significance test are presented in Table 12.

Table 12. MANOVA significance test results on critical and creative thinking ability

	Effect	Value	F	Hypothesis df	Error df	Sig.
Class	Pillai's Trace	.202	9.764[b]	2.000	77.000	.000
	Wilks' Lambda	.798	9.764[b]	2.000	77.000	.000
	Hotelling's Trace	.254	9.764[b]	2.000	77.000	.000
	Roy's Largest Root	.254	9.764[b]	2.000	77.000	.000

Based on Table 12, in the Class column the value of F = 9.764, the values of Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root have Sig = 0.000 <0.050 (significant). This shows that there is a significant influence on the PBL model with the brainstorming method on students' critical thinking ability and creative thinking on environmental change material.

Furthermore, based on Table 13, there were differences in the results of the implementation of learning by students in experimental and control classes, both of which are categorized as very good. Moreover, the implementation of learning can also be seen based on the results of the student worksheets assessment. The average value of the experimental class at each meeting is higher than the control class and it can be concluded that there is a difference in the average value of the student worksheets

in the two classes. More details, can be seen in Table 14. Then, Table 15 shows that there is no difference in the results of the implementation of learning by teachers in experimental and control classes. The average percentage value of teacher learning implementation in experimental and control classes in three meetings was 95% with a very good category.

Table 13. Percentage of learning implementation by students

The Meeting	Experimental Class	Control Class
1st	80%	78%
2nd	88%	86%
3rd	94%	91%
Average	87% (very good)	85% (very good)

Table 14. Results of student worksheet assessment for experimental and control classes

Data	Experimental Class			Control Class		
	The Meeting			The Meeting		
	1st	2nd	3rd	1st	2nd	3rd
Highest Score	78.13	87.50	93.75	78.57	84.38	91.67
Lowest Score	71.88	81.25	87.50	71.43	81.25	83.33
Average	75.78	83.20	90.23	75.00	83.20	88.02

Table 15. Percentage of Implementation of Learning by Teachers

The Meeting	Experimental Class	Control Class
1st	91%	91%
2nd	95%	95%
3rd	100%	100%
Average	95% (very good)	95% (very good)

Treatment in the experimental class that uses the PBL model with the brainstorming method, students go through a series of processes such as identifying problems, defining problems, finding solutions to problems by conveying as many opinions as possible, and evaluating them to be used as a solution to these problems which can initiate higher-level thinking. namely students' critical and creative thinking. PBL can be said to be an effective learning model because the process of problem solving, self-directed, collaborative, high-order thinking (critical and creative thinking) in the learning activity. Similar research also suggests that the PBL model is more optimal in improving critical thinking ability compared to conventional models (Batdi, 2014; Choi et al., 2014; Nurkhin et al., 2020; Temel, 2014). In addition, PBL can also improve students' creative thinking ability (Ceylan, 2022; Ulger & Imer, 2013). Birgili (2015) suggests that in the same way, the use of PBL can be used to improve critical and creative thinking ability, depending on the use of everyday cases and problems, where learners can discover new knowledge in solving problems. Birgili (2015) suggests that this PBL model can affect dual thinking ability, namely critical and creative thinking ability simultaneously, to produce different solutions can show the side of creative thinking, while reasoning ability can show the side of critical thinking. This can happen because PBL bridges students to collaborate in finding solutions and developing scientific concepts so that it can affect both dual thinking abilities (Wenno et al., 2021). Critical and creative thinking complement each other and produce quality and sustainable innovations for education (Birgili, 2015).
The implementation of learning by students can be seen in the results of observing the implementation of learning, the results show that there are differences in the results of the implementation of learning by students in the experimental class and the control class. The average percentage of learning achievement in the experimental class has the highest value compared to the average percentage of the control class and at each meeting, it has increased. This shows that using the brainstorming-based PBL model can be effective in improving students' critical and creative thinking ability. Similar to previous research this PBL model can improve critical thinking ability (Batdi, 2014; Choi et al., 2014; Nurkhin et al., 2020; Temel, 2014). In addition, PBL can also improve creative thinking ability (Ceylan, 2022; Ulger & Imer, 2013). PBL combined with brainstorming can stimulate the brain to think logically, spontaneously, and creatively (Setiawan et al., 2021). Improving students' critical and creative thinking ability is supported by the implementation of student learning which can be seen in the results of the assessment of Student Worksheets for the experimental class and the control class. The results of the student worksheets assessment in the experimental class got a higher average score than the control class and at each meeting, it increased. This shows that PBL-based student worksheets and brainstorming can improve students' critical and creative thinking ability. Applying these models and methods, students can express their opinions so that they can be effective in improving critical and creative thinking ability and the ability to communicate with their friends (Ghabanchi & Behrooznia, 2014). In addition, the application of the brainstorming method in learning, especially science, can develop critical and creative thinking ability as seen by the presence of creative ideas conveyed in teaching and learning activities because

they are given more time to convey ideas without limits on various problems (Fazila, 2017).
Teacher achievement in the learning process activities can be seen in the results of teacher observations in the experimental class and control class. The results of the teacher's achievement percentage show that there is no difference between the experimental class and the control class. The average percentage shows a constant value in the experimental class and control class and is in the very good category. This shows that in carrying out the learning process in both classes, the teacher has carried out all stages of learning well. In this study, the obstacles experienced by teachers were time constraints, considering the PBL model and the brainstorming method required a long time in the learning process. As said by Masek and Yamin (2011), the PBL model requires the long-term to require students' critical and creative thinking ability. Furthermore, it is carried out for quite a long time, so that it can optimize the critical and creative thinking abilities of students and school leaders must support the needs of educators such as fixing various complete learning facilities and facilities so that learning activities can be maximized.

Conclusion

Based on the results of the research and data analysis that has been carried out, it can be concluded that the use of the PBL model with the brainstorming method has an effect on increasing students' critical thinking ability on environmental change material, the use of the PBL model with the brainstorming has an effect on improving students' creative thinking ability on environmental change material and the use of the PBL model with the brainstorming method has an effect on improving students' critical and creative thinking ability on environmental change material. The suggestion from this research is that educators need to improve their ability to develop themselves to apply innovative learning models, methods, and strategies to maximize learning activities in class, further research should be carried out, because this research is still limited in time.
The results of this study are expected to be a consideration for educators as an effort to improve learning in the classroom to achieve high-level thinking ability, namely students' critical thinking ability and creative thinking. In addition, this research can also add new knowledge about the application of the PBL model with the brainstorming method on students' critical and creative thinking ability.

Acknowledgement

The author would like to thank the parties who have helped and direction in writing this journal. Therefore, the author would like to thank Tria Nurdiana Syamsiah, S.Pd, and SMAN 1 South Tangerang City, Indonesia. Thanks also to the reviewers who have provided input to improve this article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

I. Praminingsih: methodology, analysis, writing – original draft preparation, review, and editing. **M. Miarsyah:** writing-original draft preparation, evaluation, review, and editing. **T. H. Kurniati:** writing-original draft preparation, evaluation, review, and editing

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