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The Impact of Project-Based Learning (PjBL) Model on Secondary Students' Creative Thinking Skills

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Abstract

This study aims to identify the impact of using the project-based learning (PjBL) model compared to the direct instruction learning model on secondary school students' creative thinking (CT) skills. Quasi-experimental with pretest-posttest control group design was carried out to achieve the research objectives. Fifty secondary school students randomly chosen as experimental group (n = 25) and control group (n = 25) participated in the study. Eight essay tests were used to collect students' CT based on fluency, flexibility, originality, and elaboration indicators. Data were analyzed descriptively (n-gain) and statistically using paired t-test and independent sample t-test. The result shows that students' CT significantly improved after learning for the experimental group (n-gain = 0.47; p < 0.05) and the control group (n-gain = 0.25; p < 0.05). However, students' CT in the experimental group was significantly different compared to the control group achievement (p < 0.05). Thus, the conclusion proposed that the PjBL model significantly impacts secondary school students' CT skills on the temperature and expansion material.

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INTRODUCTION

The development of science and technology and information impacts educational goals emphasizing teaching attitudes and thinking skills such as critical, systematic, creative, and effectively collaborating with others (Asy'ari, Ikhsan, et al., 2019). Higher order thinking skills are found in almost all learning curricula in various countries (Olszewski-Kubilius & Thomson, 2015). Creative thinking (CT) is one of the essential thinking skills characterized by high curiosity and formulating various solutions for solving problems encountered (Kardoyo et al., 2020). Further explained, CT is all cognitive activities used by individuals based on a particular object faced, problem, or situation, or the form of effort made to respond to situations or problems based on the individual's cognitive capacity (Bïrgïlï, 2015). CT encourages students to formulate new and authentic designs, and different hypotheses and find new solutions in problem-solving (Young & Balli, 2014). CT is further claimed to be able to raise students' awareness of their cognitive weaknesses when trying to solve problems using different strategies, evaluating the knowledge needed both what they already have and do not have (Giancola et al., 2022). The claim is in line with several opinions that state that CT is associated with other higher-order thinking skills such as critical thinking, metacognition, and problem-solving skills (Sternberg, 2018). Critical thinking and metacognition have affective features in the form of reflection of knowledge to determine strategies that are most effective in solving the problem (Asy'ari, Hidayat, et al., 2019; Muhali et al., 2021).

CT has four core components: fluency, flexibility, originality, and elaboration (Asy'ari et al., 2021). On the other hand, CT is described with several characteristics such as flexibility, authenticity, multiple thinking, thinking fast, independence and open-mindedness in formulating new strategies in problem-solving (Gilhooly et al., 2015; Liu et al., 2015). The CT component that is often poorly understood is originality/novelty (Bïrgïlï, 2015). The component is intended for the cognitive activities of students who formulate new ideas for themselves and their peers, not ideas that others have never thought of (Sternberg, 2018). CT as a skill differs from analytical and practical thinking but is more about integrating creative processes in analytical and practical thinking (Robson, 2014). CT is a vital skill based on today's learning and environment demands that focus on technology integration (Hwang et al., 2018; Widodo et al., 2020). Unfortunately, many research results show the low thinking skills of students (Fitriani et al., 2019; Franco et al., 2017). This condition is caused by several factors, such as the use of learning models that do not encourage students to think deeply (Muhali et al., 2019), resulting in low CT students who must be followed up for solutions (Kardoyo et al., 2020).

Project-based learning (PjBL) is student-oriented learning (Crippen et al., 2016) which is often implemented to train students' active collaboration and communication (Kokotsaki et al., 2016). Furthermore, other studies have found PjBL to improve problem-solving and critical thinking skills (Husamah, 2015; Jerome et al., 2017). In line with the results of this study, Fini et al. (2018) state that authentic problem-solving-oriented learning significantly impacts students' thinking skills. On the other hand, the PjBL model was found not to improve learning outcomes, learning satisfaction (Noguera et al., 2018; Rambocas & Sastry, 2017), not to have a significant impact on the debugging component of metacognitive awareness (Tosun & Senocak, 2013), student learning motivation. (Rahardjanto et al., 2019) and not always suitable for certain materials (Grossman et al., 2019). These studies indicate the gap in the impact of PjBL on student learning outcomes in terms of effective, skill, and cognitive aspects. In CT, PjBL is stated to be effective as a teaching model to train and improve students' CT (Kardoyo et al., 2020; Yamin et al., 2020), but the research was conducted on college students and social science disciplines. So that, research at the secondary school level on physical science material needs to be done.

This study aims to identify the effectiveness of PjBL on CT secondary school students as a form of gap accommodation that has been described. CT in this study is a student's cognitive activity in solving academic problems based on four indicators of fluency, flexibility, originality, and elaboration. The PjBL is used as a guide for student learning activities in thinking, communicating, and actively collaborating through problem formulation, learning objectives, exploration, collaboration, evaluation, and artifact presentation (Arends, 2012). This research is helpful as a form of empirically proven effective learning in teaching CT students. Furthermore, the study results are expected to reduce the gap in the impact of PjBL on student learning outcomes that have been previously described.

METHOD

Research Design

Quasi-experimental research with a pre-test-post-test control group design was applied to identify the PjBL impact on students' CT. The experimental group was treated with PjBL for four weeks, while the control group was treated with the direct instruction learning model for the same amount of meetings. The initial knowledge of the experimental and control group identified with eight essay tests in the first meeting. The material used in the current study was temperature and expansion. In this material, students are oriented to contextual phenomena such as objects having heat energy that can move from objects with a high temperature to objects with a lower temperature. The object's nature is associated with the ability of the student's body to detect the level of heat and cold in the surrounding environment. Through the orientation described above, students are further taught the material of temperature and expansion through problem-oriented activities that are used as learning projects and must be completed individually and in groups. The post-test was carried out by giving an essay instrument test after all the learning meetings were conducted. The experimental group's post-test result was compared with the control group's result to examine the impact of PjBL on students' CT.

Participants

The participants in the current study were 50 secondary school students from two classes in the public secondary school in west Lombok, Indonesia. The sample was randomly selected as the experimental group that implemented PjBL consisted of 25 students, while the control group consisted of 25 students was implemented the direct learning model.

Data Collection

Students' CT was assessed by eight essay tests on the temperature and expansion material. The instrument used was validated by two experts in physics education. Table 1 shows some examples of the test instrument used in the study.

Table 1. Essay test instrument used to collect students' CT

Questions	Description
Determine the material that can be essential ingredients for making thermometers! How would you explain the choice of materials you mentioned?	Students' fluency can be seen from the number of materials mentioned by students. For example, students mention alcohol, mercury, water, mercury, bimetal, and other materials with different expansions. Furthermore, students' flexibility is shown by determining materials with different categories. In contrast, originality is shown if students can name materials that are different from the examples previously mentioned. The elaboration is shown by students' explanations regarding the materials determined as the essential ingredients for making thermometers.
 The train is a means of transportation land. Train walk in on the rail. On rail	Students' CT is assessed based on the skills of thinking fluently, flexibility, originality, and elaboration shown by students in solving the given problems. Students with good CT skills must respond to why there is a gap in the railroad tracks and when it occurs. Student responses must be related to the expansion material that has been studied. Furthermore, students show the originality of the ideas given based on the elaboration of their

Questions	Description
connection, The train has a gap. Why should there be a gap? At what time did the railroad tracks change, as the picture shows? What if the railroad tracks are exposed to the sun constantly?	knowledge of specific conditions that occur on the railroad, as described in the example of the problem.

Student responses to the instruments given at the pretest and posttest stages were assessed based on a score range of 0 (if students did not respond) to 25 (if students gave responses that met the CT indicator criteria).

Data analysis

The research data were analyzed descriptively and statistically. Descriptive analysis of pretest and posttest CT students were analyzed using the n-gain equation based on the criteria of high (gain > 0.70), moderate (0.30-0.70), and low (gain < 0.30) (Hake, 1999). The score obtained was further classified based on CT criteria adapted from Asy'ari et al. (2021) as shown in Table 2.

Table 2. Students' CT criteria

Range	Criteria
80 < CT 100	Very creative
65 < CT 80	Creative
41 < CT 65	Less creative
0 < CT 40	Not creative

Inferential statistical analysis was used to identify the effect of PjBL on students' CT. Analysis of the distribution of research data was carried out first to identify the normality of the data as a prerequisite test before using the paired t-test and independent sample t-test. Statistical analysis was carried out with the help of IBM SPSS 23.

RESULTS AND DISCUSSION

Students' CT Improvement

CT students in the experimental and control groups were found to have increased after learning. However, the improvement in the experimental group was found to be better than the control group (mean = 74.40 vs. mean = 65.00). Figure 1 shows the improvement of students' CT in both groups based on the CT indicators identified in this study, such as fluency, flexibility, originality, and elaboration. The results showed that the CT of students in the experimental group increased after learning PjBL model (Table 4) based on the CT indicator and total score. Fluency increased (mean = 20.62 ; n-gain = 0.64) with moderate category, flexibility (mean = 18.35; n-gain = 0.46) with moderate category, originality (mean = 17.04; n-gain = 0.38) with moderate category, elaboration (mean = 15.92 ; n-gain = 0.27) in the low category, and the total score (mean = 74.40; n-gain = 0.47) in the moderate category. In contrast, CT students in the control group experienced a lower increase than the increase in the experimental group based on a review of CT indicators and total scores. Fluency is a CT indicator that has increased moderately in the control group (mean = 18.50 ; n-gain = 0.50), while flexibility indicator (mean = 16.04 ; n-gain = 0.27), originality (mean = 14.92 ; n-gain = 0.09), elaboration (mean = 13.42 ; n-gain = 0.03), and the total score (mean = 65.00; n-gain =

0.25) increased with the low category. The results of the descriptive analysis also show that the CT categories of students in the experimental and control groups have different categories. Students in the experimental group were categorized as creative (65 < CT 80), while the control group was categorized as less creative (41 < CT 65).

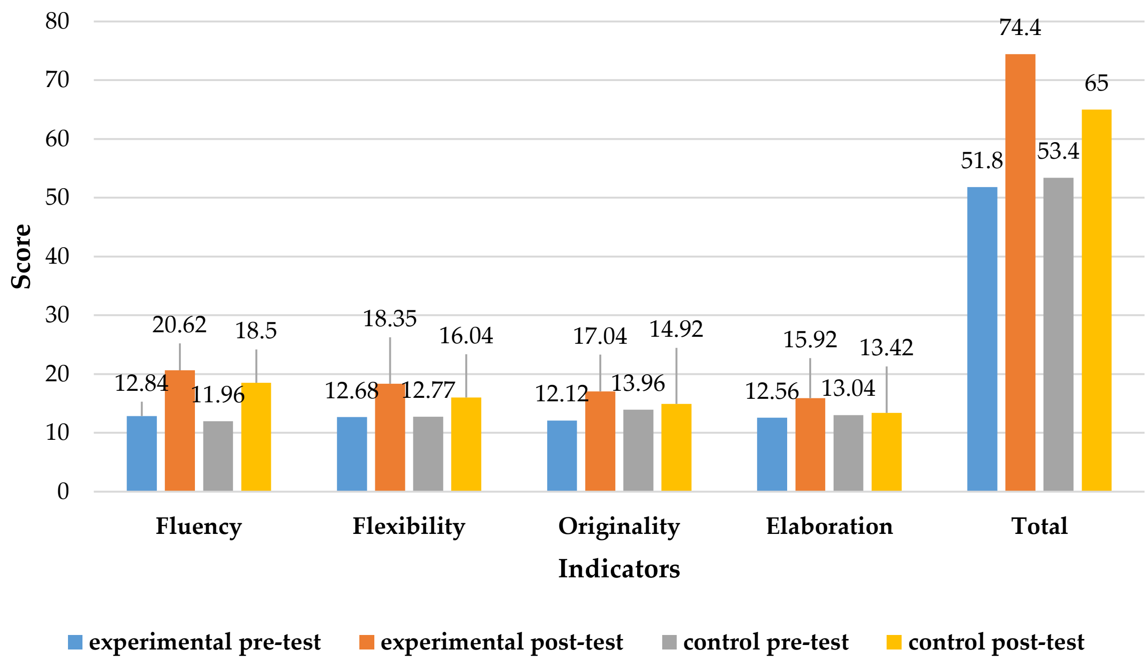

Figure 1. Students' CT improvement

PjBL Impact on Students' CT

Furthermore, inferential statistical analysis was carried out to determine the difference in the impact of PjBL compared to the direct instruction learning model on students' CT. Analysis of the distribution of research data was identified using the One-Sample Kolmogorov-Smirnov test. Table 3 shows that the experimental and control groups' pretest-posttest data were normally distributed (Sig. > 0.05). Based on the data normality test results, the analysis of differences in student CT before and after learning can be done by parametric statistical analysis using paired t-test.

Table 3. Data Normality

Group	Score	N	Students' CT			
			Mean	Std. Deviation	Sig.	Normality
Experimental	Pretest	25	51.80	4,536	0.065	Yes
	Posttest		74.40	6.344	0.060	Yes
Control	Pretest	25	53.40	13.51	0.306	Yes
	Posttest		65.00	6.614	0.350	Yes

Table 4 shows that the CT students differed significantly after learning (p < 0.05). The pretest means a score of students before learning was 51.80, while the posttest means a score of students after learning was 74.40 for the experimental group taught using PjBL. Moreover, the pretest means a score of students was 53.40, while the posttest mean score was 65.00 for the control group taught using the direct learning model. These findings indicate that H0, which states no difference in student CT before and after learning, is "rejected."

Table 4. Results of Paired t-test based on student pretest-posttest score

Pair	Score	CT Indicators				Mean	SD	p
		CT1	CT2	CT2	CT3			
Experimental	Pretest	12.84	12.68	12.12	12.56	51.80	8,912	.000
	Posttest	20.62	18.35	17.04	15.92	74.40		
	n-gain	0.64	0.46	0.38	0.27	0.47		
Control	Pretest	11.96	12.77	13.96	13.04	53.40	14.05	.000
	Posttest	18.50	16.04	14.92	13.42	65.00		
	n-gain	0.50	0.27	0.09	0.03	0.25		

Note: CT1 = Fluency; CT2 = Flexibility; CT3 = Originality; CT4 = Elaboration

Table 5 shows the results of the t-test on the posttest scores of the experimental and control groups. Students' CT in the experimental group was significantly different compared to the control group ($p < 0.05$). The experimental group's posttest means the score was better than the control group (mean = 74.40 vs. mean = 65.00). Furthermore, the value of $t = 5.128$ was greater than $t_{0.05, 48} = 1.677224$. Thus, the hypothesis H_0 that stated no significant impact of PjBL in comparison with direct learning instruction on students' CT is “rejected.” Based on the research results, it can be stated that PjBL has a better impact than direct instruction on students' CT.

Table 5. Results of independent sample t-test based on student posttest score

Group	Items	N	Mean	Std. Deviation	t	df	p
Experimental	Posttest	25	74.40	6.34429	5.128	48	0.000
Control	Posttest	25	65.00	6.61438			

The current study aimed to determine the impact of PjBL in comparison with the direct learning model on secondary school students' CT. The results showed an increase in students' CT before and after learning in the two sample groups of this study. The fluency indicator was found to have the highest increase in both groups, followed by the flexibility, originality, and elaboration indicators. On the other hand, the achievement of students' CT in the experimental group taught using the PjBL model was stated to have a significant impact compared to the direct learning model applied to the control group. The study results were caused by student activities that were more oriented toward hands-on activities in the PjBL model.

The results of this study are in line with the findings of previous research, which states that experimental-based learning allows students to solve various problems (Lince, 2016) so that it has the potential to train and improve students' flexible thinking skills (Weatherspoon et al., 2015). The results of other studies also state that students' CT can be optimized through learning carried out through projects to test hypotheses formulated by students (Lisdiani et al., 2019; Malik et al., 2019; Setiawan et al., 2018). The results of this study are under the characteristics of PjBL, which are student-oriented, emphasizing problem-solving through projects that are solved individually or in groups (Chen & Yang, 2019). Unfortunately, these studies did not use the PjBL model as a learning intervention. Furthermore, previous research was not conducted on secondary students and identified general higher-order thinking skills.

Students' CT in the experimental group was significantly better than in the control group. The results of this study cannot be separated from the activities of students who are explicitly guided in generating creative ideas through the PjBL model. The PjBL model syntax includes formulating problems, focusing on learning objectives, participating in learning activities, collaborating between students, using scaffolding, and creating real artifacts (Krajcik & Shin, 2014). In line with the study's results, Guo and Wang (2021) stated that teaching higher-order thinking skills (CT) should be taught using explicit learning models. Furthermore, several research results show that learning models accompanied by supporting tools that explicitly lead to the facilitation of higher order thinking skills show significant and positive results in improving students' academic learning outcomes (Caesar et al., 2016; Prayogi & Verawati, 2020) including students' CT.

Several research results have described the advantages of using PjBL for better student academic achievement (Jerome et al., 2017; Kokotsaki et al., 2016). Sutinen (2013) explained that the PjBL model has a philosophy of meaningful learning by providing analogies for academic problems with phenomena in the student's environment. The provision of authentic phenomena in implementing the PjBL model is in accordance with the principles of learning that can be understood, focused, and attention to students' growth and cognitive needs (Mastrothanasis et al., 2018). Modern learning demands are also accommodated in this study, requiring project-based learning to meet actual demands (Lazić et al., 2021). Learning in the experimental group integrates constructivist and cognitive-social principles, where students gain knowledge through actively constructing knowledge based on their social context. This condition is very relevant to the characteristics of CT, which demands flexibility and the ability to elaborate on the information that is used as the basis for constructing knowledge.

The advantages of the PjBL model implemented in the experimental group caused students to be more active in constructing knowledge through experimental activities than students in the control group. However, in implementing the PjBL model, several important points must be considered, such as the limited number of participants that can be accommodated in the PjBL model to achieve learning objectives successfully. The statement Condliffe (2017) reveals that the impact of the PjBL model is very promising for students' academic achievement but has not been proven. This is alleged because the PjBL model requires teachers and students to have good conceptual and procedural knowledge to participate in learning using the PjBL model (Kingston, 2018; Muhali et al., 2019). The implementation of teaching that is not in accordance with the PjBL principles has the potential to cause a negative impact on student learning performance (Capraro et al., 2016; Erdogan et al., 2016). However, this study's results align with several other studies, which found a positive impact of using PjBL on student achievement. Previous research found increased motivation, activity, and student satisfaction during learning using the PjBL model compared to students taught using the traditional instruction model (Hasni et al., 2016; Kortam et al., 2018).

CONCLUSION

The results showed that the PjBL model applied to the experimental group significantly impacted students' CT compared to the direct instruction model applied to the control group on temperature and expansion material. Based on the increase in the CT indicator, the experimental group got better results on each indicator, such as fluency, flexibility, originality, and elaboration, with a moderate improvement category. In contrast, students' CT in the control group was in a low category. The students' CT category in the experimental group was also found to be better (creative category) than the control group students' CT (less creative category).

RECOMMENDATION

The results of this study are only limited to the material of temperature and expansion. Further research with the use of other learning materials needs to be done. Furthermore, several studies state that the PjBL model has no impact and is correlated with student learning outcomes, motivation, and student learning satisfaction. Unfortunately, these variables were not identified in this study, so further research that accommodates this research gap needs to be carried out in the future.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Declaration of Interest

The authors declare no conflict of interest.

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