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Creative Thinking Skills Through Project-Based Learning (PjBL)-STEM Model

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Abstract: Creative thinking skills are important for students in generating ideas, learning, and ease of processing information. The PjBL-STEM model, in line with 21st century learning, empowers students to develop talents and abilities. This study aims to determine the improvement of students' creative thinking skills and the effect of the PjBL-STEM model on students' creative thinking skills. This type of research uses a quantitative approach with a pre-experiment method with One Group Pretest-Posttest Design. Sampling was taken using saturated sampling technique, namely all fourth-grade students of UPT SDN 173 Gresik, totalling 22 students. Data collection techniques involve giving tests with research instruments in the form of creative thinking skills questions that have been validated and are reliable. Data analysis used the N-Gain Test to determine the increase in creative thinking ability indicators after implementing the PjBL-STEM model and paired sample T-test to determine the effect of the PjBL-STEM model on students' creative thinking ability with a significance level of 0.05. The results showed that the average N-Gain value was 0.77 which means that there was an increase in students' creative thinking skills with a high category and the results of the paired sample T-test analysis obtained a significant value of 0.000> 0.05 which means that there is a statistically significant difference between the creative thinking skills of students before and after the application of the PjBL-STEM model, so it can be concluded that the PjBL-STEM model is effective for increasing the influence of students' creative thinking skills. In the broader world of education, applying the PjBL-STEM model can empower students to develop talents and abilities holistically per the demands of the 21st-century curriculum, while improving STEM literacy, collaboration skills, and learning independence. Therefore, integrating the PjBL-STEM model in the current curriculum can strengthen meaningful, relevant, and contextualized learning, and prepare students to face real-world challenges with better creative thinking skills.

Keywords: Creative Thinking; PjBL; STEM.

Introduction

Education is an important aspect of human life in today's era of globalization. Through education, individuals can develop their potential, acquire knowledge, and hone their skills. In the 21st century, education must be oriented toward the competencies required for students to master various skills known as the 4Cs: creative thinking and critical thinking (critical thinking & problem solving), collaboration, communication, and creativity & innovation [1]. Additionally, Trilling states that creative thinking is one of the skills that must be developed in the 21st century or the present era [2]. Creative thinking is a way to understand, make plans, find alternative interpretations, solve problems, and comprehend what is happening. Creative thinking is an expression of divergent thinking. Divergent thinking can be assessed based on four factors: Fluency, Flexibility, Originality, and Elaboration [3]. These four categories are a psychometric approach developed by Joy Paul Guilford and Torrance, the fathers of creativity worldwide [4].

Creative thinking skills are important to develop in students because creative thinking plays a central role in education, life, and change. These skills are needed to face the era of globalization by improving students' abilities to a higher level in taking the initiative to overcome problems, especially in the development of science [5]. These skills not only help individuals find innovative solutions to challenges but also play a role in creating opportunities and improving the quality of life in the future [6]. Science education is one of the subjects that can develop creative thinking skills in elementary school students [7]. Science education is systematic knowledge obtained through observation, experimentation, or testing, aimed at enabling students to connect what they learn with their daily lives [8]. Similarly, the science education process in elementary schools focuses on enhancing creative thinking skills through hands-on experiences, enabling students to develop competencies and understand nature scientifically [9]. Early science education is necessary to help students become more creative and innovative because this education can foster a high level of curiosity and teach students to appreciate nature and the environment. The purpose of creative thinking skills is to generate innovative ideas for creating original products or projects that include new ideas, techniques, and systems [7].

Creative thinking skills are still considered a form of thinking ability that receives little attention in education, especially in academic learning, which still focuses on knowledge, memory, and reasoning [10]. Based on initial observations conducted on 27 fourth-grade students, it was found that students' levels of creative thinking on several indicators were still relatively low. This is evident from the percentage scores on the first three indicators, which were 37.96%, 31.48%, and 38.89%, respectively, and thus can be categorized as insufficient. This condition indicates that most students still have difficulty developing ideas and thinking creatively in these aspects. However, in the fourth

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indicator, students showed better results with a percentage of 56.48%. This condition indicates the need to improve students' creative thinking skills so that they can be more active and innovative in the learning process. Additionally, previous researchers have explained that students' creative thinking skills are still relatively low and need to be improved or developed to facilitate their learning [11]. Another important aspect for teachers to consider is preparing and evaluating materials, time, problems, and activities. It is hoped that teachers can use more engaging teaching approaches or models to make the learning process more focused and impactful on improving creative thinking skills.

The PjBL-STEM model is a collaborative learning approach because it emphasizes active and group learning, as well as information sharing, which helps broaden other students' perspectives [12]. One learning model that can enhance students' creative thinking skills is the PjBL-STEM model. According to Laboy-Rush, the PjBL-STEM model has five learning stages: Reflection, Research, Discovery, Application, and Communication [13]. The PjBL-STEM learning model can be used as an innovative learning approach, where in PjBL, students are required to create a project or product, while STEM is a component that involves interdisciplinary connections [14]. The PjBL-STEM learning model can provide students with contextual learning experiences through complex activities such as exploring learning activity planning, conducting collaborative projects, and ultimately producing a product [15]. As a result, students become more active, creative, and directly involved in project creation. PjBL-STEM can increase students' interest in learning to think creatively and develop higher-order thinking skills. Additionally, the learning process becomes more meaningful and can be sustained over the long term [16].

This is evidenced by several studies that have examined the success of the PjBL-STEM learning model. Research on the Effectiveness of the STEM-Integrated Project-Based Learning Model (PjBL-STEM) on the Creative Thinking Skills of Grade X Students [17]. Implementation of PjBL-STEM to Improve Students' Creative Thinking Skills on the Topic of Static Fluids [18]. This project-based learning can improve students' creative thinking skills [19]. Researchers want to integrate the PjBL-STEM learning model in creating innovative and varied learning for students in improving their creative thinking skills. Therefore, the integration of the PjBL-STEM model in the current curriculum can strengthen meaningful learning and prepare students to face real-world challenges with better creative thinking skills. However, most of the previous studies that examined the effectiveness or influence of the PjBL-STEM model were conducted at the secondary education level or in the context of general learning without a specific focus on elementary schools. This study is different from previous studies because this study focuses on examining the improvement of creative thinking skills of elementary school students through the application of the PjBL-STEM model, thus making a more specific contribution to the context of basic education. Thus, the results of this study are expected to be a relevant reference for the development of STEM learning in elementary schools, which so far is still relatively limited in scientific studies.

Based on the background discussed above, it is necessary to conduct research to determine how the application of Project-Based Learning (PjBL) integrated with STEM (PjBL-STEM) can improve students' creative thinking skills. The purpose of this study is to determine how PjBL-STEM learning model can improve and influence students' creative thinking skills.

Research Methods

This research is quantitative research with a pre-experimental One-Group Pretest-Posttest design. In this One-Group Pretest-Posttest design, one class is used as the treatment class. With a pretest before the treatment and a posttest after the treatment, the researcher uses the following design [20];

Table 1. One-Group Pretest-Posttest Desigen

Pretest	Treatment	Posttest
O_1	X	O_2

Explanation:

O_1 : Pretest score before learning with the model (treatment)

X : Treatment of the experimental group using the model.

O_2 : Posttest score after learning with the model.

This study involved all 22 fourth-grade students in elementary school. Sampling was taken using the saturated sampling technique, which is a sampling technique where all members of the population are used as samples. This study used a pretest-posttest technique with essay questions as instruments in accordance with the indicators of creative thinking developed by Joy Paul Guilford and Torrance, covering the following aspects: (1) Fluency, the ability to generate many ideas in response to problems, both verbally and non-verbally. (2) Flexibility, the ability to see different perspectives on a problem, categorize ideas or concepts into various categories, or view situations from different perspectives. (3) Originality, rarity or uniqueness and statistical inconsistency. (4) Elaboration, the ability to develop, add detail, and implement new or given ideas [3]. The instrument has gone through a validation process by expert lecturers in the field of education and psychometrics to ensure its content validity and reliability, so that it is suitable for use in collecting research data. In addition, this research also pays attention to ethical aspects by obtaining approval from the school, guaranteeing data confidentiality, and ensuring that student participation is voluntary without coercion, in order to maintain the rights and welfare of students during the research process.

The data were analyzed using the N-Gain test. N-Gain is a comparison of maximum gain scores. The improvement in ability was taken from the pretest and posttest scores for creative thinking obtained by the students. The N-Gain test was used to determine the extent of improvement from the use of the PjBL-STEM learning model on students' creative thinking skills. The assessment was carried out by calculating the achievement scores normalized using the following formula:

$$G = \frac{\text{skor postest} - \text{skor pretest}}{\text{skor ideal} - \text{skor pretest}}$$

Table 2 is the classification of N-Gain test criteria.

Table 2. N-Gain Score Criteria

Score N-Gain	N-Gain Criteria
$0.70 < g < 1.00$	Hight
$0.30 \leq g \leq 0.70$	Medium
$0.00 < g < 0.30$	Lowly

A statistical test was conducted using a paired sample T-test to determine whether there was an effect of using the STEM-based Pjbl model on students' creative thinking abilities. The paired sample T-test can be performed if the prerequisite test, namely the normality test, has been met.

Results and Discussion

This study integrates the PjBL-STEM model to improve creative thinking skills. The PjBL-STEM model is a collaborative learning activity because it involves students working in teams or collaborating. Students develop intellectually when they engage in collaborative activities with other students who share information or knowledge, learning motivation, and a sense of responsibility [21]. The stages or syntax of the PjBL-STEM model influence the improvement of creative thinking skills, and these stages include.

In the first stage, Reflection provides each group with the opportunity to seek information through question and answer sessions on the topic of energy change. The aim is to broaden their understanding of planning and generate findings through project activities. A thought process is needed to understand the issues rationally and develop the intellectual ability to organize which aspects can be developed and which cannot.

The second stage is Research. This stage clarifies learning activities by asking students to find information that requires students to produce learning products through project activities, to the extent to which students understand the phenomena that occur. Learning by providing problem phenomena through LKPD to students is an active learning method for students to find new information independently, so that students can think about project plans, stages, objects, and decision making.

The third stage is Discovery. Students conduct a research project to discover new things that they previously learned through literature. This activity will make students think like scientists with their thinking skills to generate new ideas and facilitate the discovery of new knowledge. At this stage, students can train to develop the ability to investigate an object for the common good in the implementation process of learning activities that require students to create products through creative abilities in learning simultaneously with other students.

The fourth stage is Application. Students apply scientific activities to make or create products with various mechanisms that require tools and materials according to scientific procedures or steps. This stage integrates important information in stimulating creative thinking to obtain new findings for self-training. The creative thinking process during research and application facilitates decision-making to design a framework for obtaining data findings from research results.

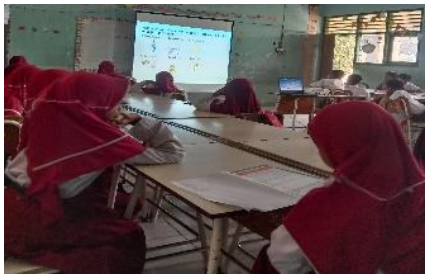

Figure 1. Research Activities

Figure 2. Discovery Activities

Figure 3. Implementation Activities

Figure 4. Communication Activities

The fifth stage is Communication. Here, students present the data findings to other groups to clarify the new things they have discovered and to provide new knowledge information for other students. At this stage, students can criticize the findings that strengthen their ability to convey their opinions through direct communication. Creative thinking skills are important in processing data findings and can be used as information for others, both in oral and written form.

The improvement in students' creative thinking skills was measured by calculating the N-Gain score of each student and looking at the average score. The average pretest, posttest, and N-Gain scores in this study, which cover the four indicators of creative thinking skills, are presented in the following table.

Table 3. Average N-Gain Scores for Creative Thinking Skills

Number of Students	Score		Score N-Gain	Category
	Pretest	Posttest		
22	48.23	88.09	0.77	Height

Students' creative thinking skills improved by 39.8 after implementing PjBL-STEM learning with an average N-Gain value of 0.77 (high category). Based on Table 3, the average creative thinking skills of students before the treatment obtained an average score of 48.23 and after the implementation of the PjBL-STEM learning model, it was 88.09. It can be concluded that there was an increase in students' creative thinking ability test results, as seen from the average pretest and posttest results and the N-Gain results, which fall into the high category.

For more details, Table 2 describes the percentage, frequency, and data scores, with each question grouped based on indicators of creative thinking skills, namely fluency, flexibility, originality, and elaboration.

Based on Figure 5, the average percentage of student test results on the creative thinking ability indicator increased in each indicator, indicating that the project-based learning method with a STEM approach (PjBL-STEM) is effective for science education to improve creative thinking skills. Student test results on the fluency indicator showed 32% on the pretest and 60% on the posttest. For the flexibility indicator, the results were 26% on the pretest and 54% on the posttest. For the originality indicator, the results were 40% on the pretest and 58% on the posttest. For the elaboration indicator, the results were 29% on the pretest and 59% on the posttest. Based on Figure 5, it can be seen that the highest average percentage increase was in the elaboration indicator, which was 29% on the pretest and 59% on the posttest, with an increase of 30%, and the lowest percentage increase was in the originality indicator, which was 40% on the pretest and 58% on the posttest, with an increase of 18%. It can be seen that each indicator of creative thinking ability has improved.

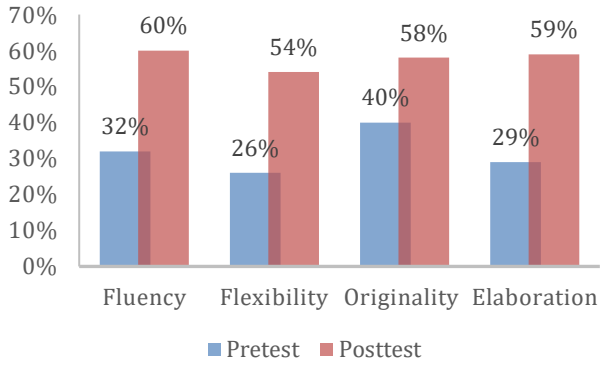

Figure 5. Graph showing the percentage of students creative thinking abilities in the pretest and posttest

The effect of the PjBL-STEM model on students' creative thinking skills can be calculated using a Paired Sample T-test statistical test of the N-Gain scores based on the pretest and posttest scores of each student with a significance level of 0.05. There are prerequisite tests before conducting the Paired Sample T-test, which include normality and homogeneity tests. The results of the normality test are presented in the following table.

Table 4. Normality Test Results

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Class	Statistic	Df	Sig.	Statistic	df	Sig.
Test value	Pre Test	.133	22	.200*	.919	22	.073
	Post Test	.140	22	.200*	.951	22	.334

Based on the normality test in Table 4, it shows that the significance value obtained from the pre-test was 0.073 and from the post-test was 0.334, which means that the significance values of both data sets are greater than the significance level (0.05). Therefore, it can be concluded that the data in this study is normally distributed.

Based on the results of the normality test, the data from this study meet the requirements for conducting a Paired Sample T-test. The results of the Paired Sample T-test are presented in the following table.

Table 5. Results of the Paired Sample T-test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Pre-test Post-test	39.864	7.815	1.666	43.329	36.399	23.925	21	.000

The results of the paired sample T-test in Table 5, with a significance value (2-tailed) of 0.000 < 0.05, indicate a significant difference between the students' conditions before and after the treatment. It can therefore be concluded that there is a difference in the average creative thinking ability of students between the pretest and posttest. Based on pair 1, it can be concluded that there is an effect of using the PjBL-STEM learning model.

Based on the results of research and data analysis, the implementation of the Project-Based Learning model with a STEM approach (PjBL-STEM) has been proven to be effective in significantly improving students' creative thinking skills. This improvement is not only seen in the

overall average score but also in each indicator of creative thinking skills, namely fluency, flexibility, originality, and elaboration. This study aligns with Mamahit [17], who demonstrated that project-based learning with a STEM approach can enhance students' creative thinking skills in the moderate to high categories. This reaffirms that the PjBL-STEM model makes a positive contribution to the development of creative thinking skills.

The implementation of learning based on the PjBL-STEM syntax, namely Reflection, Research, Discovery, Application, and Communication, shows excellent quality in supporting the improvement of creative thinking skills, which is in line with the research by Laboy-Rush [13]. The Reflection stage provides opportunities for students to search for information and understand problems in depth, thereby stimulating rational thinking and systematic organization of ideas [22]. The Research and Discovery stages further encourage students to engage in exploration, planning, and innovation independently and collaboratively, thereby strengthening creativity and scientific investigative skills [23]. The Application and Communication stages refine methodological skills and effective and persuasive scientific communication abilities, while also boosting students' confidence in presenting their findings [24].

The quantitative analysis conducted showed a significant increase in students' creative thinking abilities after the implementation of the PjBL-STEM model. The average pretest score of 48.23 increased to 88.09 on the posttest, with an average N-Gain value of 0.77, which is categorized as high. Evaluation of the indicators of creative thinking indicated improvement in all aspects, with elaboration showing the highest increase, indicating the students' ability to develop ideas in detail and depth. Although the originality indicator showed the lowest increase, this still reflects progress in generating original ideas that need to be further developed.

The results of the Paired Sample T-test with a significance value of 0.000 ($p < 0.05$) reinforce the conclusion that there is a statistically significant difference between the creative thinking abilities of students before and after the implementation of the PjBL-STEM model. The fulfilled normality test ensures that the research data meets the parametric assumptions, thereby validating the results. Thus, the PjBL-STEM model not only contributes to improving students' cognitive aspects but also builds learning motivation and a sense of responsibility through collaborative learning. Therefore, the PjBL-STEM model can be used as an effective and sustainable science learning strategy in optimally developing students' creative thinking skills.

There are also challenges that must be faced in the implementation of the Project-Based Learning integrated STEM (PjBL-STEM) model. One of the main obstacles is the limited learning time available at the elementary school level, so not all stages of the PjBL-STEM syntax can be optimally implemented in one learning cycle. In addition, differences in the initial abilities of students require teachers to apply differentiation strategies that require special readiness and expertise. The limited facilities and infrastructure supporting STEM learning are also a significant obstacle in implementing comprehensive exploration and application activities. Therefore, to improve the success and sustainability of the implementation of the PjBL-STEM model, support is needed in the form of adjusting the allocation of adequate learning time, as well as increasing relevant supporting facilities and resources.

Conclusion

Based on the research results, it can be concluded that there was a high increase in students' creative thinking skills in science learning after the implementation of the project-based learning model with a STEM approach (PjBL-STEM), as seen from the average test scores of students before using PjBL-STEM, which was 48.23, and after using the PjBL-STEM learning model, which was 88.09. This is demonstrated by the average N-Gain test results for students' creative thinking skills, which were 0.77, categorized as "high." Additionally, the Paired Sample T-test results showed $0.000 < 0.05$, indicating a significant difference between the pretest and posttest scores, meaning that the PjBL-STEM model has a significant effect on students' creative thinking skills. Overall, the PjBL-STEM learning model not only significantly improved students' creative thinking test scores but also enhanced the quality of their creative thinking in terms of fluency, flexibility, originality, and elaboration. The PjBL-STEM learning model is highly recommended for teachers as a learning strategy that supports active learning activities and focuses on scientific activities that require students to produce discovery products while improving creative thinking skills. For curriculum developers, the integration of the PjBL-STEM model should be considered as an effort to enrich learning approaches that are relevant to the demands of the 21st century, especially in developing higher-order thinking skills and STEM literacy [25],[26]. In addition, further research is strongly recommended to explore the long-term impact of the PjBL-STEM model on students' creative thinking skills and academic achievement, as well as its application in other subjects outside of science, such as mathematics, technology, and the arts, to obtain a more comprehensive picture of the effectiveness and adaptability of this model.

Author`s Contributions

Ika Putri Rahayu: Contributed to the conceptualization and design of the research, data collection, data analysis, and writing of the article. Fitria Wulandari: Supervised the entire research process, provided theoretical insights, reviewed the final draft, and submitted the article. All authors have read and approved the final draft.

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