ANALYSIS OF THE EFFECTIVENESS OF STEM-BASED PjBL MODEL TO DEVELOP STUDENTS' CREATIVITY

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Abstract: This study aims to analyze the effectiveness of the STEM-based Project-Based Learning (PjBL) model in improving students' scientific creativity on the topic "Separation of Mixtures" in class VIII of SMP Negeri 36 Jakarta. The background of this study departs from the need for science learning that is able to foster creativity and critical thinking through contextual and collaborative experiences. The method used is a quasi-experimental with a pretest-posttest non-equivalent control group design, involving two classes of 36 students each. The experimental class used the STEM-based PjBL model, while the control class applied the Discovery Learning model. Data were collected through creative thinking skills tests and analyzed with SPSS. The results showed a significant increase in students' creativity scores in the experimental class ($p = 0.000$) with a large to very large effect size based on Cohen's d calculation and Hedges' correction. These findings indicate that STEM-based PjBL has a strong practical effect in developing students' scientific creativity. In conclusion, the implementation of STEM-based PjBL is effective in improving creative thinking skills through contextual, collaborative, and challenging learning, and contributes to strengthening the science education approach that is oriented towards developing 21st-century competencies.

Keywords: Project_Based_Learning; STEM; Creativity

INTRODUCTION

Project-Based Learning (PjBL) integrated with a STEM approach can be an effective alternative teaching strategy at the junior high school level (Hanif et al., 2019). This approach is considered capable of encouraging active student engagement in the learning process, emphasizing real-world problem solving and the development of 21st-century skills. In this context, efforts are needed to enhance students' scientific creativity through learning models specifically designed to foster creative and scientific thinking skills (Ramdani & Susilo, 2022). Similarly, Beghetto and Anderson (2022) state that researchers and educators are now beginning to examine how creativity can be effectively incorporated to enhance students' learning experiences. The application of creativity in education is certainly closely related to learning practices in schools. According to Widodo et al. (2018), learning encompasses four main elements: attitude, process, product, and application, all of which are realized through meaningful learning activities. In this case, the skills developed through learning are known as process skills, while the attitudes instilled in students refer to scientific attitudes (Susilawati et al., 2020). The integration of these various elements is an important foundation in designing learning that is not only outcome-oriented but also reinforces scientific processes and values.

As society evolves, technology has evolved from a mere tool to an integral part of everyday life (Hernandez, 2017). In the educational context, the STEM approach—an acronym for Science, Technology, Engineering, and Mathematics—has emerged as a new paradigm that encourages the development of science and technology through educational policies and curricula (Sousa & Pilecki, 2018). STEM learning focuses on developing 21st-century skills such as problem-solving, creativity, critical thinking, communication, collaboration, and digital literacy. Teachers play a crucial role in preparing learning that meets these demands, requiring cross-disciplinary competencies and adequate pedagogical support (Androutsos & Brinia, 2019; Chan, Yeh & Hsu, 2019). Research shows that the current generation is ready to face the challenges of the digital age (Cedere *et al*., 2020) and that STEM implementation has been shown to improve collaboration and student learning outcomes (Aini & Kuendo, 2023). Such learning creates an environment that encourages active, innovative, and creative students (Myers & Berkowicz, 2015).

Integrating STEM into learning to foster students' creative character is still rarely done, even though a creative character will ultimately improve students' creative thinking skills (Sawu *et al*., 2023). Heliawati et al. (2022) perspective reveals that improving students' critical thinking skills is closely related to improving their creative thinking and communication skills. Therefore, learning that encourages students to explore new knowledge and ideas is essential for fostering creativity. Problem-solving in science learning not only demands critical thinking skills but also requires students to integrate their existing knowledge with new techniques to generate innovative solutions. According to Ramdani and Susilo (2022), students need to be trained to explore and imagine various problem-solving approaches, which often lead to creative new combinations of knowledge. One effective way to achieve this is through open-ended, experiment-based learning. This approach encourages students to think freely and creatively, without being limited by a single correct answer, giving them the opportunity to discover solutions independently. This strategy has been shown to improve students' conceptual understanding and problem-solving skills (Heliawati et al., 2021). Furthermore, creativity in the context of science education is not only seen from the final outcome, namely an innovative product, but also from the process students undergo in reaching that solution, which reflects original and flexible thinking.

According to Jumadi et al. (2021), creativity involves three main components: creative behavior, which relates to an individual's habits in creating something new; the creative process, which describes how information and ideas are processed into creative products; and the creative product itself, which is the end result of the creative thinking process. In developing creativity, the creative process can be divided into four main stages: preparation, incubation, illumination, and validation (Pekbay & Kahraman, 2023). In the preparation stage, a person defines the problem at hand and begins to explore various solutions. The incubation stage is when ideas are temporarily stored, giving time for the subconscious mind to work. The illumination stage occurs when a creative solution emerges spontaneously, and in the validation stage, the solution is tested to ensure its effectiveness. These four stages are important in fostering students' scientific creativity, as they allow them to practice deep and innovative thinking in solving scientific problems.

Mentoring in learning is a key element in ensuring students achieve learning outcomes relevant to real life. With the demand for 21st-century skills, such as critical thinking, communication, collaboration, and creativity, a student-centered learning approach is crucial (Suyanto, 2023). According to Thomas (2000), PjBL is significantly able to increase student engagement because it involves them in authentic tasks, which also fosters critical thinking and collaboration (Bell, 2010).

Although PjBL has been proven effective in developing essential skills, there remains a gap in the literature, particularly regarding how teacher mentoring in PjBL specifically impacts students' creativity and collaboration. Existing research tends to focus on general learning outcomes or critical thinking skills, but has not yet thoroughly explored the role of teacher mentoring as a key variable facilitating the development of these two skills. Furthermore, few studies have measured the impact of teacher mentoring on the specific interactions between collaboration and creativity in PjBL contexts in specific educational settings.

This study offers novelty by quantitatively analyzing the impact of teacher mentoring in PjBL on students' collaborative skills and creativity simultaneously. By measuring teacher mentoring variables as predictors, this study will fill the gap in the mechanisms by which teacher interventions directly influence students' creative and collaborative output. Furthermore, this study will provide new empirical evidence regarding the relationship between collaboration skills and creativity facilitated by PjBL and structured teacher mentoring, thus providing practical insights for educators and curriculum developers.

METHOD

This study used a quasi-experimental design with a pretest-posttest non-equivalent control group design. This design was chosen because it allows for comparing the effects of the treatment on the experimental group with the control group, even though participants were not randomly assigned. The research instruments required are: 1). Experimental class learning observation sheets and control class learning observation sheets. 2). Scoring guidelines for learning observation sheets. 3) Creative thinking skills tests are given with a pretest and a posttest for creative thinking. 4). Scoring guidelines for creative thinking skills. The control class and experimental class use a 4-point Linkert scale.

According to Creswell (2012), a quasi-experiment involves assigning participants to groups, but not randomly (non-random assignment). In this design, the researcher administered a pretest to both groups (control and experimental), then only the experimental group received the STEM-based PjBL blended separation learning treatment, while the control group continued with conventional Discovery Learning. After the treatment, both groups received a posttest to assess differences in learning outcomes, particularly in terms of student creativity. Furthermore, Isnawan (2020) emphasized that when a particular learning model, approach, strategy, or method is to be implemented in a classroom with naturally occurring participant conditions (for example, classes predetermined by the school), researchers cannot use random assignment, and the most appropriate design for this situation is a quasi-experimental one. Sugiyono (2016) expressed a similar sentiment, stating that a quasi-experimental design is used because, in practice, it is difficult to find a control group that is truly equivalent to the experimental group. Therefore, the groups used in quasi-experiments are usually pre-existing classes, without randomization. Gay and Airasian (2012) also added that this design is commonly used in educational research because ethical and logistical factors often make randomization of participants impossible.

In this study, the researchers designated two existing classes at the school as the research subjects. One class served as the experimental group, receiving mixed separation learning using the PjBL method with a STEM approach, while the other served as the control group, receiving conventional learning using the Discovery Learning method. Both classes were given a pretest to determine the students' initial conditions, and after the treatment, both were given a posttest to assess the effects of the treatment.

Participants in this study were eighth-grade students of SMP Negeri 36 Jakarta. The selection of class VIII was made because the material "Separation of Mixtures" is part of the topic of Elements, Compounds, and Mixtures taught in the eighth-grade science curriculum. SMP Negeri 36 Jakarta was chosen as the research location because of the availability of suitable classes, ease of access, and school support for the implementation of the research. In addition, this school represents the general characteristics of public schools in Jakarta, so the results of the study are expected to be not only beneficial for the school, but also can be adapted by other educational practitioners with similar contexts. The population in this study were all eighth-grade students of SMP Negeri 36 Jakarta in the 2024/2025 academic year. The research sample was selected purposively, taking into account the equality of initial abilities between classes based on the results of discussions with science teachers. The sample used in this study consisted of: Class VIIIA as an experimental class that participated in the separation of mixtures learning using the STEM-based PjBL method with a total of 36 students and Class VIII D as a control class that participated in the separation of mixtures learning using the conventional Discovery Learning method, also totaling 36 students. The research target profile can be seen in table 1.

Table 1. Research Target Profile

School Name	Class	Class Type	Method	Approach	Number of Students
SMPN 36 Jakarta	VIII A	Experiment	PjBL	STEM	36
SMPN 36 Jakarta	VIII D	Control	DL	Inquiry	36

The increase in student learning creativity was observed using research instruments and statistical calculations using SPSS type 27. The required research instruments were: learning observation sheets, observation sheet scoring guidelines, creative thinking skills tests, and creative thinking skills scoring guidelines. SPSS then calculated the N-Gain and significance of the resulting data.

RESULTS AND DISCUSSION

Data analysis in this quasi-experimental study was based on the principles of inferential statistics, which allow conclusions to be drawn about a population based on sample data. Specifically, because this study involved comparisons between groups and repeated measurements (pretest-posttest), the analysis techniques used aimed to identify significant differences in the dependent variable after treatment. The primary consideration in selecting statistical tests involved data characteristics, including the normality of distribution. Based on the comparison of pretest-posttest scores in both groups, the analysis focused on changes in the experimental group and the final comparison between the experimental and control groups to determine whether STEM-based PjBL learning provided significantly different effects.

An ideal learning environment should empower students to be active, innovative, and creative (Myers and Berkowicz, 2015). Creativity itself involves three main components: creative behavior, creative process, and creative product (Jumadi et al., 2021). To foster this creativity, science learning plays a crucial role, particularly one that encourages students to explore new knowledge and ideas. Therefore, students need to be trained to explore and imagine various problem-solving approaches to generate new, creative combinations of knowledge (Ramdani and Susilo, 2022).

One effective approach is to integrate STEM (Science, Technology, Engineering, and Mathematics) into learning. The STEM approach can foster students' creative dispositions, ultimately enhancing their creative thinking skills. Various studies support the effectiveness of this approach, such as a study by Pekbay and Kahraman (2023), which analyzed the effects of design-based STEM activities on scientific creativity. Furthermore, research by Zendah and Sulistina (2023) concluded that STEM-based PjBL is effective in improving students' scientific literacy and creative thinking skills. In this study, the average creativity scores of the experimental and control classes can be seen in Table 2.

	Question 1	**Question 2**	**Question 3**	**Question 4**	**Question 5**	**Question 6**	**Question 7**	**Question 8**
Average 8A	2,47	2,36	2,78	2,56	2,44	2,67	2,61	2,36
Average 8D	2,33	2,56	2,64	2,47	2,39	2,47	2,39	2,39

Overall, the pretest averages for both classes on most questions showed relatively similar scores. This is a good indication that at the beginning of the study, both groups had relatively comparable levels of ability or characteristics on the variables being measured. While there were some small differences on individual questions, there were no striking or systematic differences where one class significantly outperformed the other on all questions. These slight differences are evident in Figure 1.

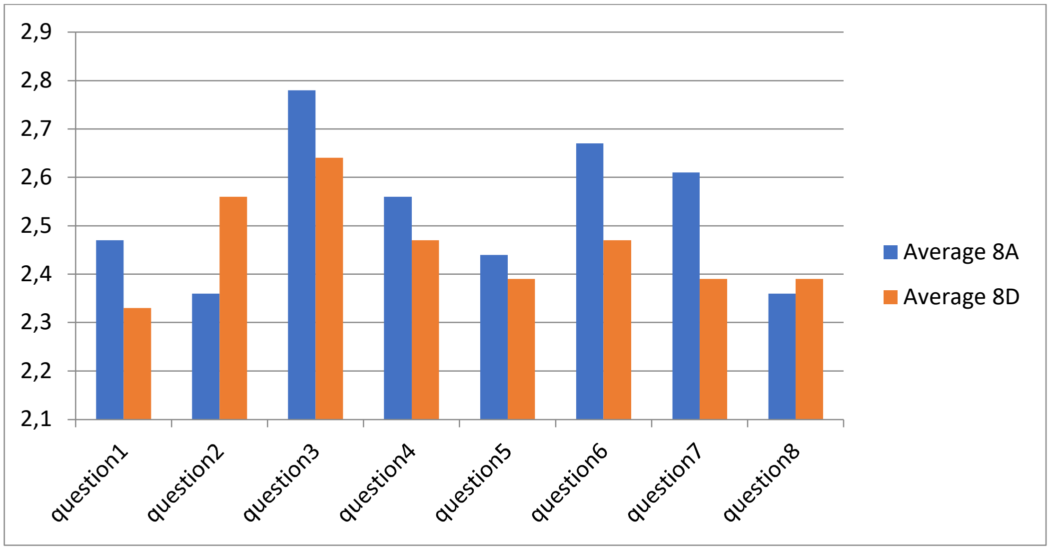

Figure 1. Diagram of the average pretest creativity of the experimental class and the control class

This pretest data will serve as an important basis for comparison with the posttest data. If, after the STEM-based PjBL learning treatment, the experimental class (8A) shows greater improvement or a significantly higher posttest score than the control class (8D), then this difference can be attributed to the effectiveness of the STEM-based PjBL learning, considering that the initial conditions of both groups are relatively balanced. Next, we will detail the statistical description of the collected data, followed by a presentation of the results of the hypothesis testing that has been conducted. Qualitative data analysis and t-tests are the most preferred analysis methods (Hebebci, M. T. 2022). Based on the research results and discussion, it can be concluded that the application of STEM-based PjBL can develop creative thinking skills (Zendah, D. F., & Sulistina, O., 2023).

The results of the paired-samples t-test for each question (x1 to x8) measuring creativity in the experimental class, including the mean, number of answers, standard deviation, and standard error of the mean, are shown in Table 3.

Table 3. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	x1begining	2.4722	36	.69636	.11606
	x1end	3.3333	36	.53452	.08909
Pair 2	x2begining	2.3611	36	.54263	.09044
	x2end	3.3889	36	.49441	.08240
Pair 3	x3begining	2.7778	36	.59094	.09849
	x3end	3.6111	36	.49441	.08240
Pair 4	x4begining	2.5556	36	.55777	.09296
	x4end	3.2778	36	.51331	.08555

Pair 5	X5begining	2.4444	36	.65222	.10870
	X5end	3.2778	36	.51331	.08555
Pair 6	X6begining	2.6667	36	.82808	.13801
	X6end	3.4722	36	.50631	.08438
Pair 7	X7begining	2.6111	36	.87105	.14518
	X7end	3.3889	36	.54917	.09153
Pair 8	X8begining	2.3611	36	.59295	.09882
	X8end	3.3889	36	.49441	.08240

From this table, it is clear that the average score on all creativity questions in the experimental class showed an increase from the initial condition (pretest) to the final condition (posttest) after the STEM-based PjBL method treatment. For further clarification, see the following diagram.

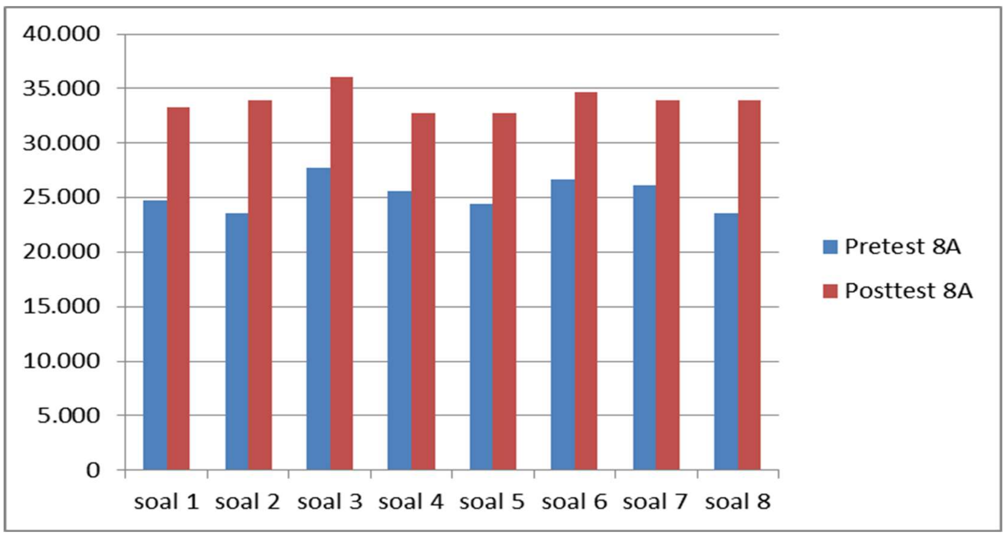

Figure 2. Diagram of the increase in the average value for each question

Next, to compare the average initial and final scores, see Table 4.

Table 4: Paired Samples Test

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	x1beginning - x1end	-.86111	.76168	.12695	-1.11883	-.60340	-6.783	35	.000

Pair 2	x2beginning - x2end	-1.02778	.60880	.10147	-1.23377	-.82179	-10.129	35	.000
Pair 3	x3beginning - x3end	-.83333	.77460	.12910	-1.09542	-.57125	-6.455	35	.000
Pair 4	x4beginning - x4end	-.72222	.61464	.10244	-.93019	-.51426	-7.050	35	.000
Pair 5	x5beginning - x5end	-.83333	.56061	.09344	-1.02302	-.64365	-8.919	35	.000
Pair 6	x6beginning - x6end	-.80556	.98036	.16339	-1.13726	-.47385	-4.930	35	.000
Pair 7	x7beginning - x7end	-.77778	.89797	.14966	-1.08161	-.47395	-5.197	35	.000
Pair 8	x8beginning - x8end	-1.02778	.65405	.10901	-1.24908	-.80648	-9.428	35	.000

It should be noted that the "Mean" here is calculated as xbegining - xakhir; so a negative value indicates an increase in score (xend > xbegining). What is very striking from this table is that for all creativity items (x1 to x8) shows a statistically significant increase in scores from pre-test to post-test (all p-values = 0.000, which is much smaller than 0.05). This means that the increase in creativity observed after the implementation of the STEM-based PjBL method in the experimental class did not occur by chance.

In addition, to find out the magnitude of the effect of the STEM-based PjBL method treatment on creativity scores, this can be seen in Table 5.

Table 5. Paired Samples Effect Sizes

Paired Samples Effect Sizes						
			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	x1begining - x1end	Cohen's d	.76168	-1.131	-1.545	-.706
		Hedges' correction	.76997	-1.118	-1.529	-.698
Pair 2	x2begining - x2end	Cohen's d	.60880	-1.688	-2.195	-1.171
		Hedges' correction	.61542	-1.670	-2.171	-1.159
		Cohen's d	.77460	-1.076	-1.483	-.659

Pair 3	x3begining - x3end	Hedges' correction	.78302	-1.064	-1.467	-.652
Pair 4	x4begining - x4end	Cohen's d	.61464	-1.175	-1.597	-.744
		Hedges' correction	.62132	-1.162	-1.579	-.736
Pair 5	X5begining - X5end	Cohen's d	.56061	-1.486	-1.958	-1.005
		Hedges' correction	.56671	-1.470	-1.937	-.994
Pair 6	X6begining - X6end	Cohen's d	.98036	-.822	-1.196	-.438
		Hedges' correction	.99103	-.813	-1.183	-.434
Pair 7	X7begining - X7end	Cohen's d	.89797	-.866	-1.246	-.477
		Hedges' correction	.90774	-.857	-1.232	-.472
Pair 8	X8begining - X8end	Cohen's d	.65405	-1.571	-2.057	-1.075
		Hedges' correction	.66116	-1.555	-2.035	-1.064

a. The denominator used in estimating the effect sizes. Cohen's d uses the sample standard deviation of the mean difference. Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

This table provides information on the magnitude of the effect of the STEM-based PjBL method treatment on creativity scores. Negative values for Cohen's d and Hedges' correction indicate an increase (Xend > Xbegining). All creativity questions show effect sizes (Cohen's d and Hedges' correction) that are large to very large (most are above 0.8, many are even above 1.0). This indicates that the STEM-based PjBL method treatment has a very strong and substantial practical impact on increasing student creativity in the experimental class. Based on the analysis of pre-post creativity data in the experimental class (8A), it can be concluded that the average creativity score on all questions (x1 to X8) shows a consistent increase from the pre-test to the post-test. The increase in creativity scores on all questions (x1 to x8) is statistically significant ($p < 0.001$ for all questions). The effect sizes (Cohen's d and Hedges' correction) indicate that the impact of the STEM-based PjBL method on increasing creativity in the experimental class is large to very large for all questions. This shows that the changes that occurred were not only statistically significant, but also had substantial practical significance. Although the pre-post correlations for most items were not significant, the t-test results and very strong effect sizes indicate that the STEM-based PjBL method effectively increased overall student creativity in the experimental class.

CONCLUSION

The results of this study indicate that the implementation of the STEM-based PjBL model was effective in enhancing students' scientific creativity in the topic "Separation of

Mixtures" in eighth-grade students at SMP Negeri 36 Jakarta. This improvement was demonstrated by a significant difference between pretest and posttest scores in the experimental group, with a large to very large effect size. The STEM-based PjBL model positively contributed to developing students' creative thinking skills through contextual, collaborative, and challenging learning. Therefore, this approach is suitable for implementation as an alternative learning strategy in science education at the junior high school level.

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