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Improving Students' Science Process Skills through The Implementation of PBL Integrated STEAM

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ABSTRACT

The poor science process skills of junior high school students in Indonesia highlight the need for innovation in learning models. Learning with an integrated STEAM PBL model can have a positive impact on the development of students' scientific process skills. This research aims to elaborate on the improvement of students' science process skills after the implementation of the PBL model integrated with STEAM. This study employed a quantitative pre-experimental design with a One Group Pretest-Posttest Design. The research sample consisted of students in class VIII-C at SMP Lab school UNESA 1. The data obtained were tested for normality, and then a paired test was performed because it only used one class. Furthermore, the data analysis was strengthened using N-gain analysis. The results of the study indicated that the integrated STEAM PBL model effectively improved students' science process skills. This was evidenced by the paired t-test results showing a P value of 0.000 not exceed 0.05, which means there was a significant difference. The mean of N-gain showed a result of 0.51, which was categorized as medium (11% of students are categorized as high, and 89% of students are categorized as medium).

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1. Introduction

The role of education is crucial as a pillar of a Nation's Development. In which education is closely integrated with the learning process (Fatmawati et al., 2022). Minister of Elementary and Secondary Education Regulation No. 13 of 2025 regarding Learning Process Standards states that learning must emphasize the development of creativity, collaboration, and communication through active, meaningful, and enjoyable deep learning for students (Permendikdasmen, 2025). Thus, education in Indonesia continues to be updated to ensure that the learning process can shape students with character and innovation. According to Wahyuningsih & Fatonah (2021), the aspects undergoing renewal include educator competence, educator quality, facilities and infrastructure, and academic aspects (education quality and curriculum tools) used. The Merdeka Curriculum shifts the focus of learning to students (student-centered), which means giving students the freedom to play an active role (Sugita et al., 2025). In the Merdeka Curriculum, character building and life skills mastery are also placed as key elements in the learning process. The focus on student character is realized through the instillation of fundamental values such as responsibility, empathy, cooperation, and honesty. In addition, space for imagination, creativity, and innovation in learning through project work is also a major driver of student creativity (Khotimah et al., 2025).

The implementation of the independent curriculum covers all subjects, one of which is IPA or Science, which is a scientific discipline that examines various natural symptoms (including the study of living and non-living things) (Marzuki, 2023). Basically, science has three main components, namely the scientific process, scientific products, and scientific attitudes (Kasturi et al., 2022). The scientific process and products are two things that cannot be separated because they are closely related in every investigation activity, thus forming scientific attitudes. Therefore, science learning emphasizes the development of process skills, which requires students to be directly involved through learning experiences that integrate science process skills (Santiawati et al., 2022). Science learning is related to science process skills because understanding and proving scientific concepts can only be achieved through investigative activities or experiments (Wahyuningsih & Fatonah, 2021).

According to Fauziah (2022), Science process skills refer to the scientific work to discover scientific concepts. In science learning, science process skills involve an investigative process that utilizes the natural environment to shape scientific attitudes and apply scientific methods. Science process skills must be developed to equip students with relevant provisions for the future and the complexities of the 21st century. Science process skills include a series of critical skills needed to conduct scientific research and experiments well (Eralita, 2023). Students' science process skills can be observed through practical activities and the investigation process in the classroom (Syahrial, 2024). Yuliati & Susianna (2023) states that the basic stages of science process skills include the skills of observing, measuring, inferring, grouping, making predictions, and communicating results. Meanwhile, the integrated stages of the science process skills involved the ability to ask questions, control variables, interpret data, formulate hypotheses, and design investigative activities (Rini et al., 2024).

In fact, various research results show that Indonesian students' science process skills have not yet reached the optimal point. This is in line with the findings of the 2022 PISA results, which noted that students' mastery of scientific literacy in Indonesia decreased by 13 points from the previous year. The significant decline in the science literacy scores of Indonesian students indicates that their ability to observe, interpret data, and explain scientific phenomena is considered poor (OECD, 2023). Students are not yet able to relate existing scientific concepts to their real surroundings, resulting in low PISA scores for Indonesian students (Rini et al., 2024). A similar problem occurs among students at SMP Lab school UNESA 1, where preliminary research shows that students have difficulty understanding science material. This is because science learning is dominated by memorization and teachers explaining the material through lectures. This is reinforced by the results of the science process skills test, which show that students still have difficulties in several science process skills, and this is in line with the results of interviews with science teachers, who confirmed that the learning models applied by teachers were limited to conventional methods in general.

Permatasari & Rahmi (2023) stated that this learning method was considered incapable of developing students' science process skills and improving the quality of learning. Learning activities that relate to authentic problems in the students' real environment are also rarely implemented. In addition, practicums or inquiries are rarely conducted in science learning due to the lack of supporting school laboratories. This condition causes students to be passive and unable to carry out the scientific process independently. This is in line with the students' statements during the interviews, which stated that they rarely carry out practicums and that they feel more motivated to learn science when there are practicums in science learning. There are solutions to overcome these problems and improve students' science process skills. Teachers can apply various innovative learning models, one of which is Problem-Based Learning (PBL). PBL is defined as a process-based learning model, in which students are presented with authentic and meaningful problem situations that aim to facilitate a holistic and integrated learning experience (Nasir et al., 2023). PBL is considered suitable for improving science process skills because its syntax is designed to accommodate these skills (Hartati et al., 2022). On the other hand, various approaches can be applied so that students understand important concepts in everyday life (Muttaqiin, 2023). One way that can be applied is by using the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach, which is a multidisciplinary learning approach that combines aspects of science, technology, engineering, arts, and mathematics to teach students how to solve real-world problems (Asti & Andriyani, 2022). The STEAM approach is considered capable of motivating students to actively engage in learning and explore skills through methods that are most suitable for each student (Pramitasari et al., 2025). The application of the STEAM approach in Problem-Based Learning (PBL) can teach students how to think creatively and find solutions to various problems in their lives (Atiaturrahmaniah et al., 2022).

Several previous studies, such as those conducted by Kasuga et al. (2022), have confirmed that the implementation of PBL is much more effective than conventional teaching in developing science process skills and improving student learning achievement. Other research by Savaş & Şeker (2022) showed that the implementation of STEM-based activities can effectively train and hone the science process skills of early childhood in terms of observing, classifying, estimating, measuring, recording data, communicating, and reasoning. Consistent with these findings, Aliyah et al. (2025) research also demonstrated the validity and effectiveness of a PBL-STEAM-based science module on simple machines in significantly improving science process skills. These findings further support the assertion that PBL-STEAM learning has a positive impact on improving science process skills. Several studies have discussed PBL in improving students' science process skills (SPS). Likewise, the topic of steam in improving students' SPS has also been discussed. However, studies examining the integrated PBL-STEAM model to improve students' science process skills have not been widely researched. Therefore, the researcher will conduct a study entitled “Improving Students' Science Process Skills through the Implementation of PBL Integrated STEAM”.

2. Method

This study is a pre-experimental design using one group pretest-posttest design. In this design, the treatment is given to one experimental class without using a control class. The effectiveness of the treatment was then analyzed by comparing the pretest and posttest scores of the groups. (Sugiyono, 2022). This research concept can be explained as follows.

Table 1. One-group pretest-posttest design procedure

Group	**Pretest**	**Treatment**	**Posttest**
Experiment	O_1	X	O_2

This research took the population of eighth-grade students at SMP Lab school UNESA 1 in the 2025/2026 academic year, with a sample of 27 students from class VIII-C. Sampling was conducted using purposive sampling techniques by selecting samples based on the science teacher's considerations, where eighth-grade students in class VIII-C were the experimental class, which had the best enthusiasm and learning activities compared to other classes, and had heterogeneous abilities in science learning, so that the research could run smoothly according to the initial plan. A pretest and posttest were utilized as the instruments for this research, taking the form of a science process skills test presented on a sheet containing 10 multiple-choice questions that assessed five different science process skill indicators. Data was collected during two meetings through the first stage, which involved administering a pretest followed by the implementation of the PBL model integrated with STEAM on the topic of additives (borax preservatives) and administering a final test containing the same questions after the treatment was given.

The research instrument used was a test sheet, consisting of a pre-test and a post-test, to determine students' achievement of science process skills on indicators before and after treatment. The science process skills test consisted of 10 multiple-choice questions, and each science process skill indicator was measured through two questions mapped as shown in the following table 2.

Table 2. Mapping of research instruments

No.	**Science Process Skill Indicators**	**Question Item Number**
1.	Observing	1, 2
2.	Questioning	3, 4
3.	Designing Experiment	5, 6
4.	Interpreting Data	7, 8
5.	Communicating Result	9, 10

The initial method employed for examining data from the science process skill test was the prerequisite assessment of normality. As the data collected in this study exhibited a normal distribution, the subsequent analysis involved employing a parametric test, specifically the paired samples t-test, to evaluate the pretest and posttest results. The selection of the paired t-test was since the research participants were derived from a singular, unified class. The fundamental decision-making criterion was as follows: a Sig. (2-tailed) value ≥ 0.05 indicated the absence of noteworthy differences. Conversely, a Sig. (2-tailed) value < 0.05 suggested the presence of significant differences. In addition, the scores obtained by the students were reinforced with N-gain analysis to measure the effectiveness of the treatment that had been carried out. The formula used to calculate N-gain is presented as follows.

$$\text{N-gain} = \frac{skor\ posttest - skor\ pretest}{skor\ maks - skor\ pretest}$$

The subsequent classification of outcomes, as seen in Table 2, is derived from the N-gain values that were acquired.

Table 3. Value category N-gain

N-gain Value	Category
$0,70 \leq n \leq 1,00$	High
$0,30 \leq n < 0,70$	Medium
$0,00 \leq n < 0,30$	Low

3. Results and Discussion

Results

This study was conducted in October 2025 in class VIII-C of SMP Lab school UNESA 1 Surabaya to describe the improvement in students' process skills (SPS) after the implementation of the PBL model integrated with STEAM on the topic of additives. In the learning process, students were given an authentic problem involving borax poisoning. After that, students conducted borax tests on several samples of meatballs available around the school and then chose the solution to the problem presented by the teacher. Documentation of student activities during learning is presented in the following figure 1.

Figure 1. Student Activities during the Boric Acid Test Investigation (Source: Personal Documentation)

The next stage was to evaluate the improvement in students' science process skills using five indicators: observing, questioning, designing experiments, interpreting data, and communicating results. Data on each student's science process skills in this study were collected from their performance on pretest and posttest assessments. The research results' scores were tested for normality to determine whether the data obtained followed a normal distribution, which helped select appropriate tests for the next step. (Faijah et al., 2022). Since the sample size in this study was less than 50, the Shapiro-Wilk normality test was applied. The results are presented in Table 3 below.

Table 4. Normality Test Results

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.141	27	.180	.951	27	.230
Posttest	.177	27	.029	.957	27	.317

a. Lilliefors Significance Correction

Referring to the information provided in Table 4, the results clearly indicate that the data scores that were achieved, encompassing both the pretest and posttest of science process skills, are normally distributed with significance results exceeding 0.05, namely 0.230 (pretest) and 0.317 (posttest). Given the results of the normality test, which are normally distributed, we will continue using a parametric test, namely the paired t-test, as shown in Figure 2 below.

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	Pretest - Posttest	-31.48148	13.50319	2.59869	-36.82317	-26.13980	-12.144	26	.000

Figure 2. Paired T-test Result

Based on Figure 2, the results show that Sig (2-tailed) is 0.000, which does not exceed 0.05. Since this value is less than 0.05, it can be concluded that the null hypothesis is not supported, leading to the acceptance of the alternative hypothesis, demonstrating a notable variation in student performance from the initial assessment to the final assessment. The mean difference of -31.48148 (negative difference) implies that, on average, students achieved better results in the posttest compared to the pretest. In other words, there was an increase of 31.48 points in science process skills scores after the implementation of the PBL model integrated with STEAM.

Furthermore, to determine how much change occurs after being given treatment with PBL STEAM, namely by comparing the average scores obtained before and after treatment in the same group using the effect size calculator (cohens'd), which is presented in the following table 5.

Table 5. Effect Size Result

	Mean (M)	**Std. Deviation (s)**	**Sample Size**	**Cohen's d**
Pretest	38.1481	19.81395	27	1.847260
Posttest	69.6296	13.72294	27	

Based on the test results, the Cohen's d effect size value was 1.847260. This value is included in the high category. This indicates that learning using the PBL STEAM model has a strong influence on students' science process skills. A high effect size value indicates that the observed differences or effects are very significant and large, so it can be said that the independent variable has a high influence on the dependent variable (Umamah et al., 2024). Therefore, the use of the STEAM-integrated PBL learning model can be said to be effective for use in improving students' science process skills.

The test results obtained were then analysed using N-gain. This was done to measure how well the PBL model integrated STEAM-enhanced learning outcomes. The percentage results of each student's N-gain score category can be seen in Figure 3 below.

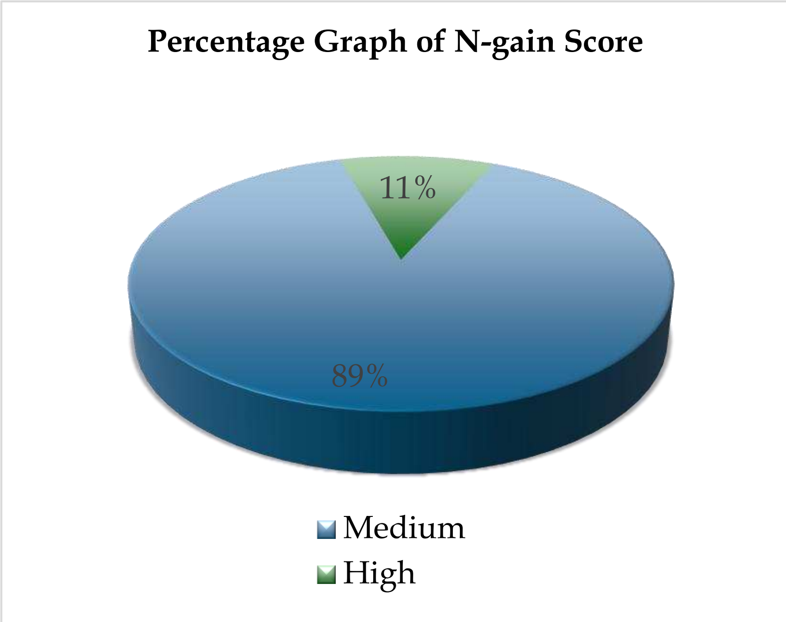

Figure 3. Percentage Graph of N-gain Score

Based on the graph above, it is evident that 89% of all students have medium N-gain scores, while the remaining 11% have high N-gain scores. The absence of students in the low category indicates that PBL STEAM learning is effective in improving science process skills in the majority of students. Students' cognitive abilities, focus while learning, and learning habits can each influence the variation in score improvement categories (Ilhami et al., 2023). The next N-gain scores were obtained by calculating each science process skill indicator presented in the following table.

Table 6. N-gain Score Results of Science Process Skill Indicators

Science Process Skill Indicators	Pretest Score	Posttest Score	Ideal Score	N-gain Score	Category
Observing	13	29	54	0,39	Medium
Questioning	23	39	54	0,52	Medium
Designing Experiment	24	39	54	0,50	Medium
Interpreting Data	24	41	54	0,57	Medium
Communicating Result	20	40	54	0,59	Medium
Mean				0,51	Medium

The results of the N-Gain calculation for the five science process skill indicators, as presented in Table 6, which are observing, questioning, designing experiments, interpreting data, and communicating results, have N-gain scores of 0.39, 0.52, 0.50, 0.57, and 0.59, respectively. The mean score obtained of 0.51 categorizes the increase as a medium category.

Discussion

The results of the study indicate that the implementation of the PBL model integrated with STEAM has a positive influence on improving the science process skills of students in class VIII-C at SMP Lab school UNESA 1. This improvement can be seen from the 5 science process skills indicators that were measured, which showed an increase from the pretest to the posttest, as proven by N-gain analysis. Most of the students' scores showed an improvement in science process skills, even though in the medium category. This research supports the existing body of knowledge regarding the beneficial effects of PBL on science education. Similarly, it aligns with studies highlighting how integrating STEAM approaches into PBL in science learning enhances students' scientific process skills. Such as the study conducted by Hariandi et al. (2023) which concluded that the N-gain test results were in the medium category and showed that students' science process skills after being given the STEAM approach were higher than before being given the STEAM approach. This is reinforced by the results of the paired t-test, which shows a Sig (2-tailed) value of 0.000, being less than 0.05. Indicating a notable variance in student scores from the pretest to the one administered later (posttest). A finding that supports the work by Ramadhan et al. (2023) proved that PBL is a superior and appropriate learning strategy compared to conventional learning methods in building essential science process skills for students in the 21st century, as evidenced by an increase in students' overall SPS scores in cycles I and II.

Based on Table 3, the performance of the science process skills indicators was statistically proven through N-gain analysis. The results categorized the increase in students' abilities from pretest to posttest as medium. The mean N-gain score obtained on the science process skills indicator was 0.51 in the medium category. The indicator with the highest N-gain score was communicating results, with a score of 0.59. The skill of communicating results is the ability to convey the results of an investigation through data tables or graphs (Wahdah et al., 2023). The next three highest N-gain scores after the indicator of communicating results were the indicator of interpreting data (0.57, medium category), the indicator of questioning (0.52, medium category), and the indicator of designing experiments (0.50, medium category). Meanwhile, the lowest N-gain analysis score was for the indicator of observation, with an N-gain point of 0.39 (medium category). According to Khotimah et al. (2023), The lack of opportunities to conduct laboratory exercises in schools is a contributing element to pupils' diminished abilities to observe. In this case, laboratory exercise should be made a habit in science learning. Students can acquire science process skills better through the PBL model, whose syntax can apply science process skills (Hartati et al., 2022). This is because the syntax in the PBL model integrated with the STEAM approach confronts students directly with real-life problems such as the issue of borax use in food sold around the students' environment. In this case, the additive material used in PBL learning is very close to everyday life and has even been experienced by students, so students more easily understand and comprehend these scientific concepts with real phenomena. With the help of the STEAM approach, visualization and contextual practice further help students in describing phenomena scientifically. In this study, students were faced with authentic problems that had to be solved through small group discussions. Then, students designed the problems that had been offered and created a poster that was then distributed to the community so that they were also aware of the dangerous ingredients that might be found in food in the surrounding environment. With this learning process, the activities within the PBL syntax can directly improve all indicators of students' science process skills. This study also confirms the findings of Kusumayuni et al. (2023) that students' science process skills are influenced by learning that integrates the STEAM approach, because the learning process requires a scientific attitude.

The implication of this study is the need for teachers to apply a learning model that prioritizes student needs and involves students in solving contextual problems (Azizah & Fauziah, 2023). This is in line with the research by Wedanthi et al. (2025), which states that the STEAM approach, combined with a problem-based learning model, helps students learn concepts through problem-solving activities that combine various fields of science. Thus, the STEAM-integrated PBL model is considered a viable, innovative alternative to overcome low science process skills (Aliyah et al., 2025). This is because PBL has a learning concept that enables students to actively seek solutions through problems that are significant to their daily lives, which are more realistic and can support students in exploring investigations through collaboration in a group (Darwati & Purana, 2021). However, there are limitations in this study, where the sample used was limited to only one class, namely class VIII-C at SMP Lab school UNESA 1, the science process skills measured were only 5 indicators, and this study was limited to implementing the PBL model on the material of additives (harmful preservatives). Suggestions for further research include conducting similar studies with a broader sample, for example, using a quasi-experimental design to compare experimental and control groups, or adding other aspects of integrated science process skills. Additionally, teachers should apply the integrated STEAM PBL model to science or other subjects in school to improve students' science process skills.

4. Conclusions

Based on all stages of analysis and discussion presented, this study concludes that the integrated STEAM PBL learning model has a positive and significant impact on improving science process skills. The average increase, which falls into the medium category (N-gain = 0.51), as well as the progress observed in each science process skills indicator, namely observing, questioning, designing experiments, interpreting data, and communicating results. These improvements indicate that the PBL model integrated with STEAM is effective in helping to improve students' science process skills.

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