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The Effect of The Project-Based Learning Model on High School Students' Science Process Skills

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Abstract

Project-Based Learning is an instructional strategy that improves students' Science Process Skills (SPS) by involving them in hands-on scientific project design and implementation. This study investigates the effect of PjBL on students' SPS, focusing on skills such as observing, generating hypotheses, planning experiments, using tools and materials, collaborating in groups, and communicating scientifically. The research follows a quasi-experimental design with a pretest-posttest control group, including two XI classes at SMAN 1 Lembar, selected through purposive sampling. One class (XI-1) is assigned to the experimental group, which uses PjBL, while the other (XI-2) is the control group, which follows traditional teaching methods. The study uses a science process skills test as the research instrument. The N-Gain analysis showed a moderate improvement of 0.335 in the experimental group, compared to a minimal improvement of 0.011 in the control group. A t-test ($t = 6.84 > t = 1.673$ at the 5% significance level) confirmed the significant effect of PjBL. The results indicate that PjBL effectively enhances students' scientific skills, critical thinking, and creativity, making it a viable and innovative approach for science education. These results suggest that PjBL can be foundational to developing more integrated, context-driven approaches to science learning.

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Keywords: Project-Based Learning, Science Process Skills, Science Learning.

INTRODUCTION

Science Process Skills are students' abilities to use scientific methods to acquire knowledge (Yalçınkaya-Önder et al, 2022). SPS play a fundamental role in science education because they serve as a bridge between theory and practice (Barut & Yüce, 2025). Students need SPS to navigate a world dominated by science and technology (Golob & Ungar, 2023). SPS also serves as an important foundation for developing critical, creative, and logical thinking skills (Ozkan & Umdu, 2021). Furthermore, SPS helps students understand scientific concepts and develop research skills (Khamhaengpol et al, 2024). The importance of SPS in science education is demonstrated by the relationship with academic achievement (Dolapcioglu & Subasi, 2022). SPS can be developed through project-based learning, as this model enhances students' creativity, activeness, and thinking skills (Ekici & Erdem, 2020).

Students' science process skills can be developed by applying project-based learning models, which can increase students' creativity, engagement, and thinking skills (McLaughlin et al., 2024). Project-Based Learning (PjBL) is a learning method that integrates concepts, skills, and competencies in a direct context by forming teams to complete specific projects (Pedro et al., 2025). PjBL is important because it encourages active student involvement in the learning process, making learning more contextual and meaningful (Cheerapakorn et al., 2024). Furthermore, the PjBL model enhances students' creativity, critical thinking, collaboration, scientific communication, and science process skills (Yang et al., 2024).

Previous studies have demonstrated that PjBL can improve students' Science Process Skills (SPS) across various education levels (Xie et al., 2025). Research on the effect of project-based learning positively impacted science process skills and learning motivation at Candimulyo 1 State Senior High School regarding environmental change (Hamidah et al., 2023). The PjBL model significantly improved the Science Process Skills (SPS) of grade 10 students in measurement at Balinggi 1 State Senior High School (Firda et al., 2024). Further evidence suggests that a Project-Based Learning approach fosters greater improvement in young learners' science process skills than conventional classroom practices. Project-Based Learning

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effectively enhances students' achievement in science process skills, such as observing, classifying, and interpreting data (Jeong, 2025). Furthermore, the developed project-based learning tools are highly valid for improving students' science process skills (Ching et al., 2021).

However, most research still focuses on science process skills indicators that students have already mastered, such as observation and classification, leaving other indicators under-recognised. Implementing the PjBL model often faces time, cost, and project complexity constraints. In addition, interviews with chemistry teachers at SMAN 1 Lembar revealed that they had never applied the PjBL model to the topic of reaction rate. The results of student interviews revealed that learning tends to be monotonous without practicum activities, particularly in the topic of reaction rates.

In light of the challenges presented, a more refined Project-Based Learning model is essential to advance learners' science process skills. This approach should specifically target the indicators that are still lacking, while simultaneously preserving and reinforcing competencies that have already been developed. This research focuses on developing six aspects of science process skills: observation, grouping, communication, hypothesising, using tools and materials, and planning experiments on topics related to reaction rate. PjBL reliably develops science process skills by considering the limitations of time, resources, and student abilities, while encouraging the integration of investigative activities, collaboration, and critical thinking into the learning process. The expected implication of this research is to provide an effective, practical learning model that teachers can implement to improve students' science process skills, and to serve as a reference for the future development of innovative, contextual chemistry learning strategies.

MATERIALS AND METHODS

Time and Place

Data collection took place over two weeks, from 16 to 30 September 2025, at SMAN 1 Lembar, a government-run senior high school in the Lembar area of West Lombok, West Nusa Tenggara, Indonesia.

Research Design

To determine how much a project-based learning strategy influences high school students' science process abilities, this study used a quantitative design. The two research groups were chosen using one-stage cluster sampling in a quasi-experimental, non-equivalent control group framework. Both classes took a pre-test at the beginning. Afterward, the experimental group participated in Project-Based Learning exercises, while the control group received regular instruction. This allowed for a comparison of the students' performance under the two situations. According to Campbell and Stanley (1963), this method is a basic experimental design in which two groups are initially assessed with a pre-test to determine their initial performance levels. The experimental group is then exposed to the intervention, whereas the control group receives no special treatment. Later, a post-test is given to both groups to gauge their learning improvement. In the current study, the experimental class engaged in four Project-Based Learning sessions, whereas the control group received instruction using a traditional format for the same amount of time. To compare the efficacy of the two teaching strategies, a post-test measuring improvements in students' chemical science process abilities was administered following the intervention.

Table 1. Research Design

Group	Pre-test	Treatment	Post-test
Experimental	T_1	O	T_2
Control	T_1	X	T_2

Description:
T_1= Pretest Results
T_2= Posttest Result
O = Project-Based Learning Model
X = Conventional Model

Population and Sample

For this research, all Grade 11 students at SMAN 1 Lembar in the 2025/2026 academic session were considered the population, representing 163 learners across five classes. Sampling was conducted using a probability-based one-stage cluster sampling method, which involves selecting a specific group and using all members of that group as the sample (Almulhim et al., 2025). Two groups were selected using this selection technique: class XI-1, with 28 pupils, was assigned to the experimental condition, while class XI-2, with 29 students, served as the control group. The study focused on two key variables: students' science process abilities in chemical reaction rate concepts as the dependent variable, and the use of a project-based learning approach as the independent variable (Tolcha et al., 2020). To gather data, the study employed a multiple-choice assessment that measured a range of chemical science process skills spanning observing, categorizing, analyzing, forecasting, generating hypotheses, designing experiments, and synthesizing conclusions. The instrument was created in accordance with a reaction-rate specification grid and was supplied in pre-test and post-test forms. Additionally, it has undergone validity and reliability tests, which verified the measures' precision and consistency (Jagirani et al., 2022).

Research Procedure

This research procedure follows the stages of experimental research outlined by Cook & Campbell (1979), including preparation, implementation, and analysis of results. It aligns with Creswell's (2014) view that procedures must describe systematic steps from planning to evaluation. The Pretest-Posttest Control Group Design was the study methodology employed (Fraenkel et al., 2012). During the preparation phase, the researcher used a one-stage cluster sampling approach to identify the experimental and control classes and developed verified learning tools and research instruments. A pre-test was given to both classes to start the implementation phase. Over the course of four sessions, the experimental class was given a Project-Based Learning (PjBL) treatment. On the other hand, over the same period of instruction, the control group received training using a traditional method. To assess the efficacy of the two learning models, a post-test measuring changes in students' chemical science process abilities was administered after therapy was completed.

Data Analysis Techniques

This study employed several analytical steps, beginning with prerequisite tests and then proceeding to hypothesis testing. The prerequisite tests were necessary to confirm that the data satisfied fundamental statistical requirements before any inferential analyses were conducted. Normality of the dataset was assessed using the Shapiro–Wilk test within SPSS, a method particularly suited for sample sizes under 50. Under this test, data are regarded as normally distributed when the p-value exceeds 0.05, whereas values at or below this threshold indicate deviation from normality (Shapiro et al., 1968). Furthermore, variance homogeneity was evaluated using Fisher's exact test (F-test), calculated using the following equation: $F = \frac{Lergest\ Variant}{Smallest\ Variant}$. Then, to calculate the variance of each group, use the following formula:

$$S^2 = \frac{\sum(x - \bar{x})^2}{n - 1}$$

Description:

F = Homogeneity index
S^2 = Variance
x = Student score
$\bar{x}$ = Average score
n = Number of samples

The calculation results are then compared with the F_{table} at a significance level of 5%. If $F_{count} < F_{table}$, then the two samples are said to be homogeneous; conversely, if $F_{count} \geq F_{table}$, then the samples are not homogeneous (Box, 1978). Hypothesis testing was conducted using two approaches: the N-Gain test and the t-test. Students' growth in competence and conceptual mastery was evaluated through the N-Gain analysis, which quantifies learning improvement by comparing outcomes before and after the instructional intervention. The N-Gain metric was derived using the Hake equation (Phylactou et al., 2025): $Ngain = \frac{posttest\ score - pretest\ score}{score\ max - pretest\ score}$. The N-Gain values obtained are then interpreted into three categories, which are presented in Table 2.

Table 2. Interpretation of N-Gain

Score N-gain	Interpretation
-1,00 < g < 0,0	There is a decrease
g = 0,0	No improvement
0,00 < g < 0,30	Low
0,30 < g < 0,70	Medium
0,70 < g < 1,00	High

(Source: Hake, 2014)

To further examine whether the two groups differed in their learning performance, a t-test was employed. The analysis followed the computation procedure outlined by Arikunto (2017):

$$t_{count} = \frac{\bar{g}_1 - \bar{g}_2}{S_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Description:

$\bar{g}_1$ = Average N-Gain of experimental class
$\bar{g}_2$ = Average N-Gain of control class
S_p = Pooled variance
n = Number of subjects

The decision-making criteria at the 5% significance threshold are as follows: if tcount is greater than ttable, the null hypothesis (H0) is rejected and the alternative hypothesis (Ha) is supported. Conversely, if tcount is smaller than ttable, H0 is accepted, and Ha is dismissed.

RESULTS AND DISCUSSION

Result

Pretest Results

Table 3 displays the pretest results for the experimental and control groups.

Table 3. Pretest Results for Both Classes

Criteria	Experimental Class	Control Class
N	28	29
Number of Scores	1110	1080
Average	39	37
Lowest Score	20	20
Highest Score	70	60
Standard Deviation	13,5	11

It is clear from Table 3 that the experimental group did better than the control group in terms of mean, maximum score, and standard deviation.

Posttest Results

The posttest results for the experimental and control classes are shown in Table 4.

Table 4. Posttest Results for Both Classes

Criteria	Experimental Class	Control Class
N	28	29
Number of Scores	1970	1420
Average	70	49
Lowest Score	40	30
Highest Score	100	70
Standard Deviation	13,7	11,7

The average minimum, maximum, and standard deviation of the experimental class are larger than those of the control class, as Table 4 illustrates. The pretest and posttest results in the experimental and control groups showed significance levels of 0.022 and 0.010 for the control group and 0.020 and 0.086 for the experimental group, according to the Shapiro-Wilk test for normality. We may infer that the data from both tests were normally distributed in both groups, as all p-values were greater than 0.05. Fisher's F test was then used to assess homogeneity, as shown in Table 5.

Table 5. Results of the Data Homogeneity Test

Statistic	Pretest	Posttest
N	57	
α	0,05	
F_{table}	1,89	
F_{count}	1,50	1,37
Conclusion	Normal	Normal

Table 5 shows that the pretest and posttest scores for both the experimental and control groups are consistent, as evidenced by the F-count being less than the F-table value, after confirming that the data are typically distributed and homogeneous, the N-gain test is carried out. The results of the N-gain test are illustrated in Figure 1.

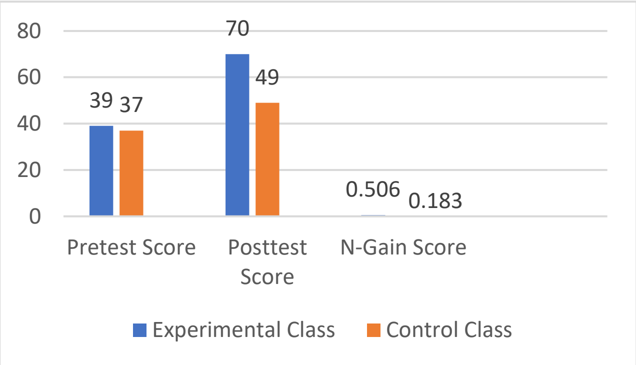

Figure 1. N-Gain Values of the Experimental Class and the Control Class

The experimental class showed a greater gain in learning outcomes than the control class, as shown in Figure 1. The control class's improvement was in the low improvement range (0.00 < g < 0.30), but the experimental class's improvement was in the medium range (0.30 < g < 0.70). Hypothesis testing was conducted to determine whether there was a significant difference in the increase in posttest scores between the experimental and control groups. Table 6 displays the test's findings.

Table 6. Hypothesis Test Results

Variable	t-test	
	Experimental Class	Control Class
Average N-Gain($\overline{g}$)	0.506	0.183
t_{count}	2,357	
t_{table}	2,004	
	(df=55, α= 0,05)	
Conclusion	H_0 rejected	

Table 6 shows that tcount exceeds ttable, leading to rejection of the null hypothesis (H0) and acceptance of the alternative hypothesis (Ha). This supports the conclusion that project-based learning has a notable effect on improving chemical science process skills related to reaction rates in the experimental group compared to the control group among XI students at SMAN 1 Lembar. A comparison of the Science Process Skills indicators for both groups is shown in Figure 2.

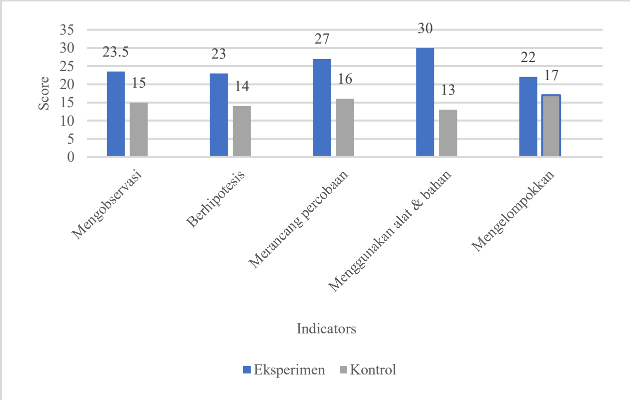

Figure 2. Comparison of Science Process Skills Scores of the Two Classes

The experimental class outperformed the control group on all science process skills indicators, as seen in Figure 2, with their proficiency with tools and materials showing the best results.

Discussion

The science process skills indicator with the most significant difference between the two classes was the one for using tools and materials, at 17. This was applied in the experimental class, as project assignments made students more skilled with tools and materials by allowing them to apply their knowledge during project implementation. Research directly observed this during project demonstrations. Demonstrations are an effective tool for helping students understand and develop their skills with tools and materials (Pringle & Knight, 2025).

The two courses were expected to have nine different science process skills. The experimental group's use of a project-based learning strategy, which encouraged students' logical thinking through autonomous project-based assignments, was responsible for this result. According to Sol´e-Llussa et al., (2021), developing hypotheses can stimulate further questions and curiosity, help students understand objectives, and provide guidelines for designing more structured projects. The experimental group's use of a project-based learning paradigm accounted for the 11-point difference in experiment planning ratings between the two groups. This approach places a strong emphasis on hands-on learning, allowing students to participate in real-world projects and apply their academic knowledge actively. Planning experiments helps students see how theory can be implemented in practical work. This aligns with constructivist learning theory, which holds that students are trained to solve problems to stimulate their curiosity, thereby making learning more meaningful (Basaga et al., 1994).

The experimental and control groups differed by 8.5 according to the observation indicator scores. The experimental class, with its practical activities, directly engaged students in learning and provided hands-on experience through their senses. This contrasted with the control class, which tended to listen only to teacher explanations and not engage in practical work, thereby preventing students from using their senses optimally, as did the experimental class. Conventional learning models tend to involve students less directly, with teachers being more dominant in transferring knowledge without actively engaging them in the learning process (Mesnan et al., 2023). The two classes' ratings on science process skills differed by five points. This resulted from the experimental group's requirement that students classify their experiment findings utilizing a project-based learning methodology. Conversely, the control group used a traditional instructional method. Students were tasked with recording observations based on the presented images. Conventional learning models often treat students as passive listeners, receiving information from the teacher or from reading materials without much active engagement. This results in a shallow understanding and underdevelopment of skills in gathering, evaluating, and synthesizing information in literature reviews (Sideri & Skoumios, 2021).

The difference in the communication indicator scores between the two classes was 13.5. The experimental class was required to present their project results. Practical activities play a crucial role in making learning more meaningful by providing students with hands-on experience and active engagement. Roth & Roychoudhury (1993) found that the advantages of practical learning include improving students' cognitive and psychomotor abilities and providing more meaningful learning outcomes. This contrasts with the control class, which tended to present discussion results based on literature rather than practical work. A weakness of the literature review method in learning is its lack of direct empirical support for practical learning experiences, particularly when empirical research is absent to substantiate the claims or theories presented in the literature (Tobin et al., 1990).

CONCLUSION

The study's findings show that the project-based learning approach is effective in enhancing students' abilities in the scientific process, especially in reaction rates. Significant improvements in pre-test and post-test scores, as well as an average N-Gain score of 0.506, which is within the moderate range, support this. By fostering an active, interactive learning environment, this approach helps students master abstract chemical concepts. However, more work is required to help students develop higher levels of science process abilities. It is advised to develop additional teaching techniques that account for each student's specific requirements and traits to accomplish this.

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