




IMPACTS OF THE POGIL LEARNING MODEL COMBINED WITH A SETS APPROACH ON CHEMICAL LITERACY AND SCIENCE PROCESS SKILLS IN THE CONTEXT OF BUFFER SOLUTIONS

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ARTICLE INFO	ABSTRACT
<p>Keywords: POGIL; SETS; Chemical Literacy; Science Process Skills; Buffer Solution</p> <p>Article History: Received: 2024-02-29 Accepted: 2024-04-29 Published: 2024-04-30</p> <p>*Corresponding Author Email: budihastuti@staff.uns.ac.id doi:10.20961/jkpk.v9i1.85057</p>  <p>© 2024 The Authors. This open-access article is distributed under a (CC-BY-SA License)</p>	<p>This study evaluates the impact of the Process Oriented Guided Inquiry Learning (POGIL) model combined with a Science-Technology-Society-Environment (SETS) approach on chemical literacy and science process skills within buffer solutions. Employing a quasi-experimental design with a nonequivalent control group, the research involved 71 students divided into experimental and control groups. Cluster random sampling was utilized for participant selection, and Multivariate Analysis of Variance (MANOVA) was applied to test the hypotheses. The findings reveal a significant effect of the POGIL learning model integrated with a SETS approach on simultaneously enhancing students' chemical literacy and science process skills. This outcome is substantiated by the MANOVA results, which indicate a significance level of 0.000, falling below the threshold of 0.05, thereby leading to the rejection of the null hypothesis (H₀). Notably, the experimental group demonstrated significant improvements compared to the control group. Chemical literacy in the experimental group reached 79.90%, significantly higher than the 62.53% observed in the control group. Additionally, the N-gain scores for the experimental and control groups were 0.70 and 0.32, respectively, categorized as high and medium. Furthermore, the percentages of science process skills were 91.61% in the experimental group and 82.37% in the control group, both in the very good category. These results underscore the effectiveness of combining POGIL with a SETS approach in elevating chemical literacy and science process skills, suggesting this method is a potent educational tool in chemical education.</p>
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INTRODUCTION

Polystyrene The Industrial Revolution 4.0 represents a phase in knowledge evolution where the physical, digital, and renewable energy realms converge [1]. This rapid knowledge transformation era necessitates educators to devise new strategies and innovations to enhance educational readiness [2]. A prevalent issue within the education sector is the need for

more student readiness for learning, coupled with low literacy levels and diminished interest in educational pursuits. More literacy skills are needed to prevent the spread of unreliable information and the emergence of indiscriminate acceptance without critical evaluation. This often leads to argumentative conflicts that can escalate into broader societal discord. Consequently, Indonesia's youth must develop robust literacy skills

across diverse disciplines to effectively process information and navigate social challenges.

Addressing the challenges of globalization requires proficiency in science literacy. Individuals with science literacy skills can apply scientific knowledge to resolve real-world problems, create beneficial scientific outputs, and adapt to the evolving global landscape. Specifically, chemical literacy is essential for students to comprehend the ongoing advancements in science and technology [3]. This study focuses on fostering chemical literacy and situating chemistry education as a crucial component of science education. Chemical literacy encompasses the ability of students to identify, analyze, and utilize chemical concepts to solve practical problems and communicate solutions effectively [4]. The significance of chemical literacy extends beyond academic achievement; it is vital for students' appreciation of nature and their capacity to leverage science and technology.

According to the Programme for International Student Assessment (PISA) data, published triennially by the Organization for Economic Cooperation and Development (OECD), Indonesia ranks among the bottom five countries worldwide in terms of student competencies in science, reading, and arithmetic [5]. This data, which encompasses around 70 countries, shows Indonesian students achieving an average score of 393 in science literacy, significantly below the global average of 500 [6]. This indicates a critical deficit in the science literacy levels among Indonesian students.

Several factors may contribute to this low performance, including the education

system and curriculum, the pedagogical methods and learning models employed by teachers, and the availability of learning facilities and resources. A notable issue impacting the development of chemical literacy specifically is the limited variety of learning models teachers utilize. Effective chemistry education in the 21st century demands creativity in selecting and implementing learning models [7]. Moreover, the teaching and learning process should foster mutual interaction and not be solely teacher-centric [8]. Additionally, students often need help to relate chemical concepts to real-life contexts, indicating low chemical literacy levels. This issue stems from inadequate preparation in exploring science-related subjects, which diminishes chemistry education's perceived relevance and effectiveness.

An inquiry-based approach is essential to enhance students' literacy skills, as science literacy involves understanding science as a concept, a process, and its real-world applications. POGIL represents a strategic educational method that can effectively boost students' literacy in chemistry [9]. Through POGIL, students engage actively in small groups, exploring and applying knowledge, fostering a deeper understanding and capability in scientific inquiry.

Education is fundamentally aimed at helping students reach their full potential and acquire practical skills for everyday life [10]. Among these essential skills are science process skills, which enable students to learn science like scientists. These skills include practicing, classifying, observing, and reasoning [11]. The specific science process skills developed in this study include

observing, predicting, making hypotheses, conducting experiments, interpreting data, concluding, and communicating. According to a study referenced in [12], science education should encompass the interrelationship among multiple dimensions: the conceptual dimension of science, the process dimension, the technology dimension, and the community dimension, all of which are critical for a comprehensive understanding of science.

The significance of science process skills has prompted research across various educational levels, including elementary by [13], junior high by [14], and high school by [15]. One learning model that effectively incorporates Science Process Skills is the POGIL model. Extensive research, including that by [16], demonstrates that the POGIL strategy enhances students' chemical literacy and science process skills, particularly on topics such as chemical bonding. Similarly, [15] found that POGIL plays a significant role in empowering science process skills. Practical activities integral to the POGIL approach are also instrumental in developing these skills, as indicated by [17], which shows that POGIL simultaneously teaches learning content and process skills.

To make chemistry more applicable to real-life scenarios, this study employs the Science, Environment, Technology, and Society (SETS) approach, which integrates science topics with environmental, technological, and societal issues. The SETS approach is designed to create contextualized chemistry learning that enhances students' chemical literacy [18]. Supporting this, [19] found that integrating POGIL with Socio-Scientific Issue content significantly increases student engagement and fosters science

literacy skills. This study emphasizes the integration of the POGIL model with the SETS approach, investigating its impact on chemical literacy and science process skills. This combination has yet to be extensively explored in previous research.

METHODS

1. Research Design

This study employs a quantitative approach using a quasi-experimental method. The research design implemented is a nonequivalent control group design, which includes two distinct groups. The experimental group receives treatment using the POGIL model integrated with the SETS approach. In contrast, the control group undergoes treatment with the Discovery Learning model, which teachers commonly use.

Table 1. Nonequivalent Control Group Design

Class	Pre-test	Treatment	Post-test
Experiment	P ₁	X ₁	P ₂
Control	P ₃	X ₂	P ₄

X₁ = POGIL model with SETS approach;
 X₂ = Discovery Learning model;
 P₁ = Pre-test results from experimental class;
 P₃ = Pre-test results from control class;
 P₂ = Post-test results from experimental class;
 P₄ = Post-test results from the control class.

2. Participants

The study's population comprised all students from four classes within the eleven-grade science program, totaling 143 students. Specifically, the science program 1 class, with 35 students, and the science program 2 class, with 36 students, were selected as the research sample using cluster random sampling. This method ensures that group samples are taken randomly [20]. The Science Program 2 class used the Discovery Learning model as the control group. In contrast, the Science Program 1 class was

designated as the experimental group utilizing the POGIL model integrated with the Science SETS approach.

Table 2. Research participation data

Experiment Group		Control Group	
Female	Male	Female	Male
23	12	24	12

3. Procedure

The research procedure was conducted in three stages:

a. Preparation stage

Researchers developed learning devices, crafted measurement instruments based on specific indicators, prepared supportive media for the learning process, and tested these instruments in non-sample classes.

b. Implementation Stage



Figure 1. LKPD with SETS element

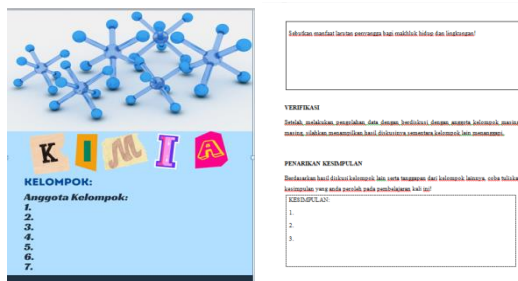


Figure 2. LKPD without SETS elements

This stage involved administering chemical literacy pre-tests of descriptive questions to the sampled classes. The

experimental class engaged in activities using the POGIL model with a SETS approach. Specifically, SETS-based Learning and Knowledge Development Platforms (LKPD), incorporating science, environment, technology, and society elements, were utilized during the POGIL model's application stage. Conversely, the control class employed the Discovery Learning model complemented by lecture methods without integrating SETS elements in their buffer solution application.

c. Final Stage

This stage involved processing and analyzing data to determine the impact of the POGIL model with a SETS approach on chemical literacy and science process skills, culminating in the research conclusions.

4. Data collection techniques

This study employed both test and non-test data collection techniques. The non-test method utilized was the documentation method, which gathered information from school records, including scores from the Midterm Examination and the Final Examination of Semester 1 for the Chemistry Class in the science program during the 2022-2023 school year. Additionally, a science process skills observation sheet with a Likert scale was used to measure students' science process skills during practicum activities. For the test method, data collection instruments included literacy questions in a descriptive format related to the topic buffer solution.

5. Data Analysis Technique

Before analyzing the data, calculate and describe the percentage achievement of chemical literacy indicators, students' science process skills, and N-Gain score.

The formula calculated the percentage of chemical literacy achievement:

$$\% \text{ LK} = \frac{\text{score obtained}}{\text{maximum score}} \times 100 \quad (1)$$

The formula calculates the percentage of KPS from the results of the observation sheet research:

$$\% \text{ KPS} = \frac{\text{score obtained}}{\text{maximum score}} \times 100 \quad (2)$$

The N-Gain Score test was conducted in conjunction with percentages of chemical literacy and science process skills to assess the effectiveness and improvement of chemical literacy skills post-treatment post-treatment. The N-Gain score formula is defined as:

$$\langle g \rangle = \frac{(S_{post}) - (S_{pre})}{100\% - (S_{pre})} \quad (3)$$

Table 3. N-Gain Effectiveness Interpretation Category

Gain Factor (g)	Criteria
$(g) > 0,7$	High
$0,3 \leq (g) \leq 0,7$	Medium
$(g) < 0,3$	Low

The analysis involved two preliminary tests: a normality test and a homogeneity test, followed by hypothesis testing using the Multivariate Analysis of Variance (MANOVA). The MANOVA test helps to determine if multiple variables change significantly simultaneously [21]. The hypotheses tested were:

H_0 : The POGIL learning model and the SETS approach do not affect students' chemical literacy and science process skills.

H_1 : The POGIL learning model with the SETS approach significantly affects students' chemical literacy and science process skills.

RESULTS AND DISCUSSION

1. Implementation of the POGIL Model

The Process Oriented Guided Inquiry Learning (POGIL) model is an evidence-based, student-centered learning framework

designed to enhance communication, problem-solving, and collaborative skills and deepen content understanding [22]. The structure of the POGIL model comprises five stages: orientation, exploration, concept formation, application, and closing [23]

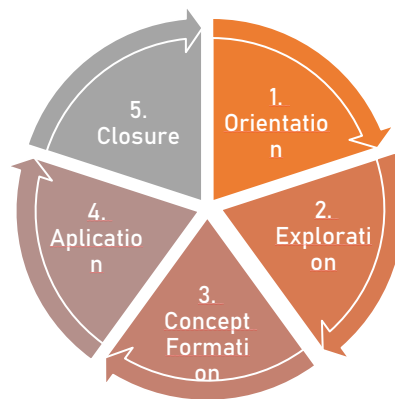


Figure 3. The syntax of the POGIL model

During the **orientation stage**, the teacher outlines the learning objectives and standards for learning outcomes, motivates student engagement, and provides resources such as narratives, illustrations, demonstrations, or videos for student analysis. In the **exploration stage**, students identify necessary factors and assess observations from their activities. The **concept formation stage** involves the teacher prompting students with questions that foster critical and analytical thinking related to their exploratory activities. At the **application stage**, students utilize new ideas in exercises, problem-solving tasks, and research, which may include conducting simple experiments within the classroom setting. The final stage entails students validating their findings by presenting them, which allows them to receive feedback on the content and quality from peers and the teacher.

The POGIL model has been shown to significantly enhance students' chemical literacy and science process skills, primarily by enabling them to apply concepts effectively. This model fosters a research-based inquiry learning environment where students actively engage in small groups to explore pre-designed materials. These activities are structured to assist students in reconstructing and applying their knowledge effectively.

2. Integration of the SETS Approach

The SETS approach can be interpreted as one that contains concepts and processes associated with the four elements of science, environment, technology, and

society to analyze and apply these concepts and processes to real life.

Science is the study of natural phenomena and their properties. The term "environment" refers to all biotic and abiotic things that exist in the life process and have a relationship with it, including social issues. Technology is defined as the products of science and art from the fruits of human civilization that can cause science to develop. At the same time, society uses the three aspects themselves, namely science, technology, and the environment. The application of SETS elements can be seen in [Table 4](#).

Table 4. Application of SETS element

Application of Buffer Solution	SETS element Science	Environment	Technology	Society
Buffer system in blood	Carbonate buffer comprises carbonic acid (H_2CO_3) and its conjugate base bicarbonate (HCO_3^-).	Low oxygen levels in the mountains can cause climbers to exhale more CO_2 , forming H_2CO_3 when dissolved in water.	Phosphate buffers help maintain a blood pH of 7.4.	Mountain climbers without supplemental oxygen can suffer from alkalosis, increasing blood pH.
Buffer systems in the industry	Citric acid, a buffer, exhibits citric properties	Citric acid is a natural and harmless organic acid ($\text{C}_6\text{H}_8\text{O}_7$) used as a preservative.	In ice cream production, citric acid prevents fat separation.	Citric acid is utilized in the pharmaceutical industry (12%), food and beverage industry (70%), and other industries (18%).
Buffer solution in soft drinks	Fizzy drinks contain phosphate ion buffers that maintain drink pH.	Sparkling water is named for its sodium salts that enhance the quality of certain non-alcoholic beverages.	Buffer solutions help fizzy drinks remain stable and consumable longer.	Adults and teenagers widely consume soft drinks.
Buffer solution in hydroponic plants	Buffer solution is very useful for maintaining the pH of plants. Hydroponics generally uses a pH range of 5.5-6.5, with an optimal number of 6.0.	After KH_2PO_4 buffer is applied to plants, when it rains or water is added, the pH remains in the optimal range.	Hydroponic fertilizer concoctions must use buffers. Buffer or buffer solution serves to stabilize pH.	For those who like gardening, especially those who cultivate hydroponic plants, buffer solutions are very useful for maintaining plant pH

3. Effect on Chemical Literacy and Science Process Skills

a. Normality test

The normality test is carried out to determine whether the sample data obtained are normally distributed. The normality test in this study uses Levene's test method with a significance level of 0.05.

Table 5. Normality Test Results of the Difference between Pretest-Posttest Chemical Literacy

No.	Class	Sig.	Conclusion
1	POGIL	0.110	Normal Data
2	Discovery Learning	0.098	Normal Data

Based on the results of the normality test of the difference in posttest-pretest scores, it is known that both groups have a significance value of >0.05 , namely 0.110 for the experimental class (POGIL with SETS approach) and 0.098 for the control class (Discovery Learning) where it can be concluded that the data from both classes are normally distributed.

b. Homogeneity Test

The homogeneity test was carried out to determine whether the data studied

was homogeneous using the Levene Statistical test with a significance level of 0.05.

Table 6. Homogeneity Test Result

Dependent Variable	Significance	Conclusion
Chemical Literacy	0.904	Homogeneous
Science Process Skills	0.109	Homogeneous

The results indicate that the significance values are greater than 0.05, specifically 0.904 for the posttest-pretest difference in chemical literacy and 0.109 for the observation sheet data of Science Process Skills. These findings confirm that the data are homogeneous in variance. Given that the data meet the normal distribution and homogeneity criteria, hypothesis testing can proceed using parametric statistical tests.

c. Pretest and Posttest data results

The findings of this research are based on the analysis of quantitative data derived from a chemical literacy test. The pretest and posttest scores for chemical literacy are summarized in [Table 7](#).

Table 7. Chemical Literacy Pretest and Posttest Score Data

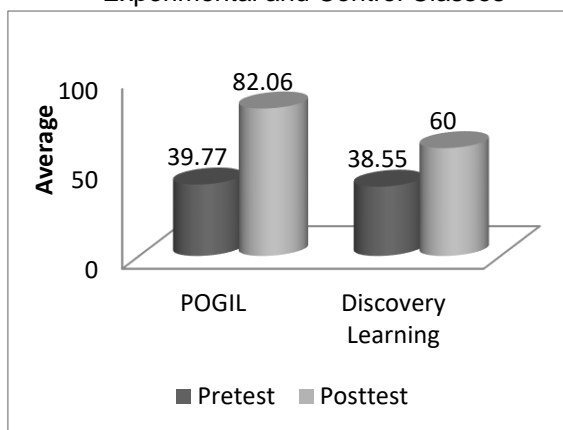
Data	Number of students	Minimum Value	Maximum Value	Average
Pretest Experiment	35	20	64	39.77
Control Pretest	36	16	56	38.55
Experiment Posttest	35	40	96	82.06
Control Posttest	36	44	72	60

Initially, students were assessed on their chemical literacy through a pretest. After

receiving distinct treatments in both classes, students were administered a posttest. The

data reveals that the average pretest scores were relatively low, indicating a general lack of chemical literacy before intervention.

Figure 3. Comparison Chart of Average Pretest-Posttest Scores of Experimental and Control Classes



The results demonstrate a significant improvement in the experimental group's posttest scores compared to their pretest scores, highlighting the effectiveness of the treatment. The control group also showed improvement but to a lesser extent than the experimental group. This contrast underscores the potential impact of the

educational interventions applied to the experimental group.

4. Analysis and Interpretation

a. Chemical Literacy Achievement Data

The percentage achievement of students' chemical literacy shows a substantial difference in the experimental class, with pretest results at 39.44% and posttest results at 79.90%. In contrast, the control class showed pretest results at 37.97% and posttest results at 62.53%. This indicates a significant difference in chemical literacy skills between the POGIL learning model with a SETS approach and the Discovery Learning model.

In the experimental class, students trained in the POGIL model could apply scientific phenomena or practical applications of buffer solutions through various stages, fostering a research-based inquiry learning environment where students actively explore material in small groups, enhancing their understanding and application of knowledge.

Table 8. Percentage Achievement of Chemical Literacy Based on Posttest Results

No	Chemical Literacy Indicators	Chemical Literacy Percentage Achievement (%)	
		Experimental Class (n=35)	Control Class (n=36)
1	Able to explain phenomena using chemical concepts	78.41	75
2	Use understanding of chemistry to solve problems	89.87	43.69
3	Analyze the strategies and benefits of chemical applications	71.43	68.89
	Average	79.90	62.53

This statement is corroborated by the results of N-Gain Score testing, which indicates that the experimental class using the POGIL model with the SETS approach is in the "high" category with a value of 0.70. In contrast, the control class (Discovery

Learning) falls into the "medium" category with a value of 0.32. This aligns with previous findings that demonstrate the effectiveness of the POGIL model in enhancing students' science literacy skills in specific scientific contexts [24].

Table 9. N-Gain Score data

Class	Average		$\langle g \rangle$	Criteria
	Pretest	Posttest		
Experiment	39.77	82.06	0.70	Tall
Control	38.55	60	0.32	Currently

This study employs three chemical literacy indicators pertinent to the competency achievement goals and syntax of the POGIL learning model [25]. The first indicator assesses the ability to explain natural phenomena using chemical concepts, encompassing nominal literacy—recognizing chemical concepts. Post-treatment results show chemical literacy levels of 78.41% in the experimental group and 75% in the control group.

The second indicator evaluates the use of chemical knowledge to solve problems, incorporating functional and multi-dimensional literacy. This indicator reached the highest achievement of 89.87% in the experimental class, significantly higher than the control class's 43.69%. N-Gain Score results of 0.84 in the experimental class and 0.14 in the control class further underscore the superior chemical literacy outcomes in the experimental group compared to the control group.

The third indicator focuses on analyzing the strategies and benefits of chemical applications, involving conceptual literacy, which assesses the ability to articulate chemical concepts in everyday phenomena. Post-treatment scores were 71.43% in the experimental and 68.89% in

the control classes. N-Gain Scores of 0.59 in the experimental class and 0.51 in the control class indicate that chemical literacy concerning this third indicator was higher in the experimental class, which utilized the combined POGIL and SETS approach. The SETS approach involves tackling real-world problems with integrated science and technology components. It creates a dynamic learning environment that enhances students' abilities to think scientifically and develop essential social skills [26]. This approach has significantly improved students' science literacy, fostering a deep understanding and effective problem-solving capabilities [27].

b. Science Process Skills Achievement Data

Two observers conducted observations on buffer solution material during the practicum. The Science Process Skills (KPS) assessed included observing, predicting, hypothesizing, conducting experiments, interpreting data, concluding, and communicating. Figures 4 and 5 illustrate the percentage achievements of science process skills in the experimental and control classes.

Observing the initial science process skill saw a percentage achievement of 88.21% in the experimental class compared to 87.5% in the control class. Observing skills are fundamental and, hence, are typically mastered easily by students.

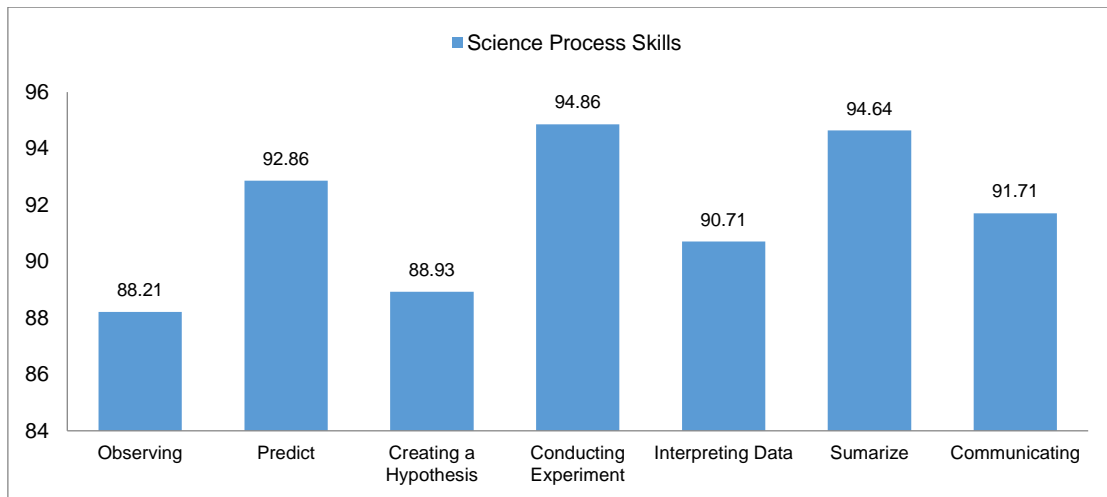


Figure 5. Experimental Class Science Process Skills Percentage Chart

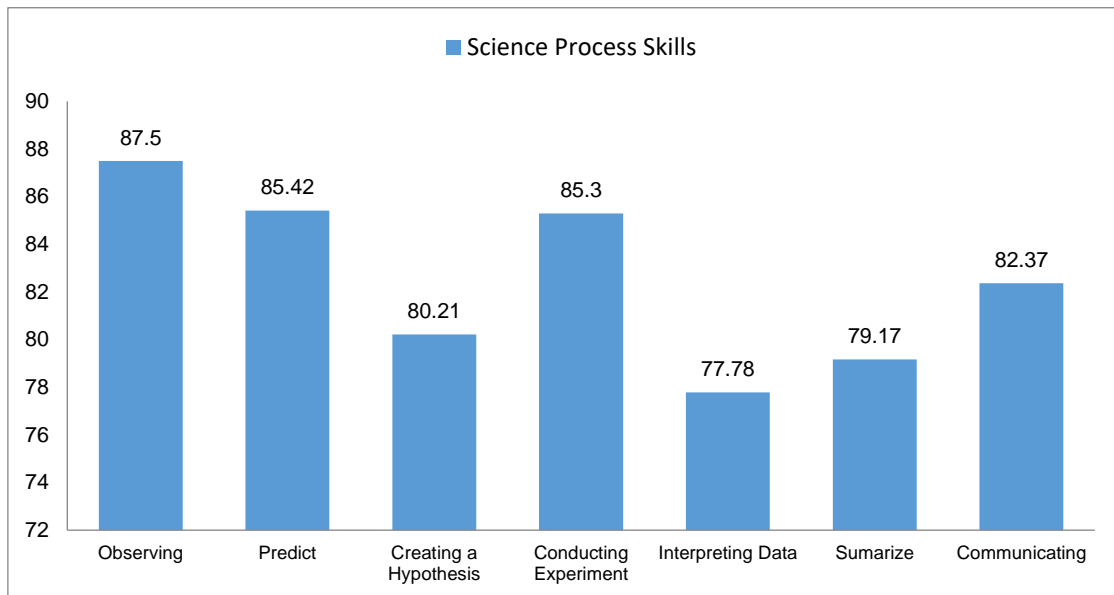


Figure 6. Control Class Science Process Skills Percentage Chart

The skills of predicting, making hypotheses, and conducting experiments were more pronounced in the experimental class that utilized the POGIL learning model with a SETS approach, compared to the control class, where the Discovery Learning model, supplemented by lectures, did not adequately support the development of these experimental skills. During the concept formation stage, students actively and independently grasped the material,

preparing them to formulate hypotheses and then apply their understanding during the application stage. This stage involved demonstrating simple experiments using practical tools and materials in the classroom. Most students in the experimental class clearly understood the experimental procedures and executed them effectively. This proficiency can be attributed to their understanding of the experiment's objectives, steps, and the anticipated data interpretation.

This observation aligns with previous studies [28], highlighting that the SETS approach encourages active thinking and enables students to implement scientific methods effectively.

The skill of interpreting data achieved 90.71%, which was categorized as very good in the experimental class. In contrast, in the control class, it reached 77.78%, which was categorized as good. In the experimental class using the POGIL model with a SETS approach, students were adept at interpreting data from experimental results during the application stage. Conversely, in the control class utilizing the Discovery Learning model, students needed more direct training in interpreting practicum observations during learning sessions. Consistent with findings that emphasize enhancing data analysis skills through hands-on classroom activities, the KPS value is categorized as high, indicating that practical activities can significantly boost students' knowledge and their ability to perform science process skills in data analysis [29].

Inferential skills were also assessed, which involve deducing an object's state based on known facts, data, concepts, and principles. Summarizing skills in the experimental class reached 94.64%, rated very good. In contrast, the control class achieved 79.17% and was rated good. In experimental classes implementing the POGIL model, students were systematically trained to draw conclusions based on known facts. During the application stage, students conducted experiments, analyzed data, and then formulated conclusions based on their experimental results. This process allowed

students to conclude direct learning experiences, enhancing their mastery of science process skills, as all student knowledge is derived from their experiences [30].

c. Hypothesis testing

The results of hypothesis testing using Manova can be seen in the Table 10.

Table 10. Hypothesis Test Results

Aspect	Significance	Test Decision
The difference in Chemical Literacy Posttest-Pretest Scores and Science Process Skills (KPS) Scores	0,000	H ₀ is rejected

Based on the table, the significance value is 0.000; if the value is less than 0.05, then H₀ is rejected, so it can be concluded that there is a significant effect of the POGIL learning model with the SETS approach on the chemical literacy and science process skills of students simultaneously.

The hypothesis testing employing MANOVA revealed a significance value of 0.000, confirming the statistically significant impact of the POGIL learning model integrated with the SETS approach on enhancing students' chemical literacy and science process skills. This result led to the rejection of the null hypothesis (H₀), illustrating the effectiveness of these interactive and contextual teaching models in improving educational outcomes in science education. The findings suggest that such methodologies actively engage students and bolster their understanding and application of scientific concepts [31].

The dismissal of H0 emphasizes the critical role of innovative teaching approaches in science education. By merging POGIL with the SETS approach, educators can foster a dynamic learning environment that enhances active participation and promotes inquiry-based learning experiences, leading to improved educational outcomes and a deeper understanding of scientific concepts [32].

Multivariate analysis of variance (MANOVA) to assess the influence of different teaching approaches on students' learning outcomes reflects methodological rigor in evaluating the effectiveness of educational interventions. This emphasizes the importance of teachers' beliefs and attitudes in shaping learning experiences, ultimately impacting students' educational achievements [33]. The broader implications of this study extend to the development of teacher education programs that focus on effectively preparing future educators to implement innovative teaching practices in science education [34].

CONCLUSION

There is a significant influence after applying the POGIL learning model with the SETS approach to students' chemical literacy and science process skills simultaneously or together. This achievement is shown from the MANOVA test results, which show a significance of $0.000 < 0.05$. For future researchers and educators, the findings of this study offer valuable insights and can be a reference for applying the POGIL model and SETS approach in chemistry teaching.

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