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The Effect of *Process Oriented Guided Inquiry Learning* (POGIL) Model on Science Literacy and Problem Solving Skills of Class XI Students of SMA Negeri 14 Gowa

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ABSTRACT

This study aims to examine the effect of the Process Oriented Guided Inquiry Learning (POGIL) model on scientific literacy and problem-solving skills of Grade XI students at SMA Negeri 14 Gowa. The research employed a quasi-experimental design with a nonequivalent control group. The sample was selected using purposive sampling, involving two classes: XI A3 (experimental group), which received the POGIL intervention, and XI B2 (control group), which received direct instruction. Data were collected using an essay test for scientific literacy and a multiple-choice test for problem-solving skills. The instruments consisted of four essay questions and nine multiple-choice items. The data were analyzed using Analysis of Covariance (ANCOVA) with a significance level of 0.05. The ANCOVA results showed a significant effect of the POGIL model on scientific literacy ($p = 0.008 < 0.05$), with mean scores of 77.97 for the experimental group and 68.40 for the control group. Similarly, a significant effect was found on problem-solving skills ($p = 0.000 < 0.05$), with mean scores of 85.97 and 77.63 for the experimental and control groups, respectively. These findings indicate that the POGIL model has a statistically significant positive impact on students' scientific literacy and problem-solving skills.

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1. INTRODUCTION

In the era of globalization and the Industrial Revolution 4.0, education has an increasingly heavy responsibility to produce individuals who are not only academically superior but also have 21st century skills, including scientific literacy and problem-solving abilities (OECD, 2024). These skills have an important role to play in an ever-changing society, where new and complex challenges continue to emerge, both in academic contexts and in everyday life.

Research shows that problem-solving skills enable individuals to identify, analyze, and resolve problems effectively.(Brenner & Uebernickel, 2016). However, data shows that the problem-solving skills of students in Indonesia are still low, where they tend to only memorize the concepts taught without being able to apply them to solve problems in their surrounding environment (Jufrida et al., 2020). The results of the Programme for International Student Assessment (PISA) survey from 2018 to 2022 show that although Indonesia rose six ranks, the average science literacy score is still very far from the global average, which is 383 points, and 102 points behind the world average score. This indicates that Indonesian students mostly only master theoretical material without knowing its application in real contexts (OECD, 2024). According to Harlina et al., (2020), lack of curiosity of students in the learning process, their inability to connect various science concepts, and the lack of role of educators in providing opportunities for students to develop critical thinking skills, are the main causal factors of this situation.

Scientific literacy, which includes understanding and applying scientific concepts in real contexts, is essential for students to be able to solve everyday problems effectively.Grace (2017)emphasizes that individuals who have scientific literacy will use these skills to solve problems in everyday life and create useful scientific products. Scientific literacy is also an important provision for students to face complex global challenges (Hurd, 1998). Therefore, improving science literacy is very important to ensure that students not only understand the theory but can also apply it in real situations, so that they are better prepared to face future challenges (Aiman et al., 2020).

Observational studies at SMA Negeri 14 Gowa showed that although educators were aware of scientific literacy, they did not actively guide students to engage in learning processes that could improve scientific literacy and problem-solving skills. Students memorized more and were less involved in active learning. These findings indicate the challenges faced by students in applying knowledge to everyday situations and that their involvement in problem-solving remains limited.

Amidst these challenges, Process Oriented Guided Inquiry Learning (POGIL) emerged as an effective learning model to improve students' problem-solving skills and scientific literacy. POGIL is based on the principle of constructivism, which allows students to learn through small group interactions consisting of 3-5 people (Kussmaul, 2014). In POGIL, students engage in discussions, problem solving, and application of science concepts in real contexts (Moog & Spencer, 2008). This approach not only improves problem-solving skills but also strengthens overall scientific literacy.

Recent research supports the effectiveness of POGIL in improving scientific literacy and problem-solving skills. Sutrisno and Nasir (2024) in their study found that the implementation of POGIL in science classes significantly improved students' conceptual understanding and scientific literacy, especially in biology. Similar results were also found by Zahro & Fauziah (2024), who showed that students who learned using POGIL had better abilities in connecting scientific concepts with real-life contexts compared to those who learned through traditional learning methods. This study shows that students involved in POGIL have higher learning motivation and greater curiosity.

Rambe et al., (2020) asserted that POGIL improves problem-solving skills by encouraging students to think critically and work collaboratively in small groups. In POGIL, students are given problems that they must solve using the knowledge they have acquired. This process trains their critical thinking skills and gets them used to applying theoretical knowledge in real-life contexts.

The effectiveness of POGIL in improving problem-solving skills is also confirmed by Warfa (2016), who showed that this model encourages learners to develop creative and innovative solutions. Through a collaborative learning process, learners are encouraged to share ideas, discuss solutions, and reflect on their thinking processes, which ultimately improves their problem-solving skills.

Research by Siahaan et al., (2021) also found that the implementation of POGIL improves students' ability to integrate knowledge from various disciplines. The results of this study indicate that students involved in POGIL are not only able to solve problems related to science, but also have the skills to connect science concepts with other fields, such as mathematics and technology, which are very important in the era of the Industrial Revolution 4.0.

With increasing empirical evidence on the effectiveness of POGIL, it is increasingly clear that this model can be an effective solution to improve students' scientific literacy and problem-solving skills. Various studies have shown that POGIL provides opportunities for students to engage in a more active, collaborative learning process that focuses on deep understanding and application of scientific concepts. Therefore, the application of POGIL in science learning is expected to have a positive impact on the quality of education.

This study aims to determine the effect of the POGIL model on students' scientific literacy and problem-solving skills. Given the importance of these two skills in the modern world, the results of this study are expected to provide meaningful contributions to the development of more innovative and effective learning methods. In addition, this study is also expected to be a reference for educators and policy makers in designing a curriculum that is more relevant to global needs and supports students to be better prepared to face the challenges of an increasingly complex worl (Rahayu et al., 2021).

2. RESEARCH METHOD

This research is a quasi-experimental research involving two classes, namely the experimental class and the control class. The experimental class applied the learning model*process oriented guided inquiry learning* (POGIL), while the control class used the Direct Instruction model. The study was conducted in the even semester of the 2024/2025 academic year at SMA Negeri 14 Gowa, located at Jl. Poros Malino KM 2, Somba Opu District, Gowa Regency. The research design used was nonequivalent control group design. In this design, classes are not selected randomly, but are determined directly based on considerations of student learning outcomes. Both groups will be given an initial test (pretest) and a final test (posttest) to measure the effect of the POGIL model on scientific literacy and problem-solving skills.The research design model can be seen in the following table.

Table 1.Research Design

Class	*Pretest*	Treatment	*Posttest*
Experiment	L1 K1	X1	L2 K2
Control	L3 K3	X2	L4 K4

Source:(Sugiyono, 2021)

Information:
L1 and L3 :science literacy ability test before treatment
K1 and K3 :test of problem solving skills before treatment
X1 :treatment given using the process oriented guided inquiry learning (POGIL) learning model
X2 :treatment given using a model direct learning *instructions*
L2 and L4 :science literacy ability test after treatment
K2 and K4 :test of problem solving skills after treatment

This research was conducted at SMA Negeri 14 Gowa with a quantitative approach and using a quasi-experimental method, namely nonequivalent control group design. The study aims to determine the effect of the POGIL learning model on students' scientific literacy and problem-solving skills. The population in this study were all 170 students in grade XI. The sample was selected by purposive sampling based on the characteristics of academic ability equality and class heterogeneity. Class XI A3 was designated as the experimental class and class XI B2 as the control class, each consisting of 30 students.

The research procedure consists of three stages: preparation, implementation, and completion. The preparation stage includes the preparation and validation of instruments, such as pretest-posttest questions and POGIL-based LKPD. The implementation stage is carried out in four meetings, with a pretest at the beginning and a posttest at the end. The experimental class uses the POGIL model, while the control class uses direct instruction, the final stage is data collection and analysis to draw conclusions.

Data collection was carried out by providing instruments in the form of essay tests and multiple choices to students as research samples. This test was used to measure scientific literacy and problem-solving skills through pretest and posttest. The score for each question was determined based on the assessment rubric, then converted using the Arikunto formula (2010). Science literacy values are categorized according to the Ministry of Education and Culture (2017) guidelines:

Table 2.Guidelines for Categorizing Scientific Literacy

Value Interval	Category
90-100	Very high
80-89	Tall
70-79	Enough
60-69	Low
< 60	Very Low

For problem solving skills, analysis is carried out based on the following Polya stages:

Table 3. Scoring Guidelines for Problem Solving Ability

Rated aspect	ResponseLearnersto the Problem	Score
Understanding the problem (understanding)	1) Write down correctly what is known and what is asked in the question.	4
	2) Write down what is known and what is asked in the question, but one of them is not quite right.	3
	3) Write down what is known or what is asked in the question correctly.	2
	4) Write down what is known and/or what is asked in the question but is not quite right.	1
	5) Not writing down what is known and what is asked.	0
Planning	1) Write the mathematical model correctly and completely so that it leads to the correct answer.	4
	2) Writing a mathematical model correctly but incompletely so that it leads to the wrong answer.	3
	3) Writing a mathematical model that is not precise but complete, leading to the wrong answer.	2
	4) Writing mathematical models incorrectly and incompletely, leading to wrong answers.	1
	5) Did not write down the mathematical model used.	0
Implementation of the plan (solving)	1) Complete with proper procedures and do calculations correctly.	4
		3

Rated aspect	ResponseLearnersto the Problem	Score
	2) Completed with the correct procedure but made a mistake in the calculation. 3) Does not use procedures in solving but is correct in doing calculations. 4) Solving with inappropriate procedures and calculations. 5) There is no resolution at all.	2 1 0
Review (checking)	1) Write conclusions correctly and check answers properly. 2) Writing the conclusion correctly but not quite right in writing the answer to the question. 3) Writing the conclusion correctly but not writing the answer correctly or vice versa writing the answer correctly but not writing the conclusion. 4) Writing conclusions and/or checking incorrect answers. 5) Not writing conclusions and checking answers.	4 3 2 1 0

Source: (Davita & Pujiastuti, 2020)

Then the scores obtained are converted into a range of 0-100 and the problem solving category is determined, as follows:

Table 4. Problem Solving Categories

Mark	Criteria
$80 \leq X \leq 100$	High
$60 \leq X < 80$	Medium
$X \leq 60$	Low

Source: (Davita & Pujiastuti, 2020)

The research instrument consisted of a multiple-choice test for scientific literacy based on indicators from Gormally et al. (2012):

Table 5. Science Literacy Indicators

No.	Science Literacy Indicators	No. Question
1.	Identifying valid scientific opinions	1
2.	Evaluating the validity of sources	2
3.	Evaluating the use and misuse of scientific information	5
4.	Understanding the elements of research design and how they impact scientific findings	3
5.	Creating a graphical representation of data	6
6.	Reading and interpreting graphical representations of data	4
7.	Solve problems using quantitative skills, including basic statistics	7
8.	Understanding and interpreting basic statistics	8
9.	Making inferences, predictions, and drawing conclusions based on quantitative data	9

(Gormally et al., 2012)

and essay tests for problem solving skills based on indicators from Polya (1973):

Table 6. Problem Solving Skills Indicators

No.	IndicatorSkills Solution to problem	No. Question item
1.	Understanding the problem	1
2.	Make a plan	2
3.	Implementing the plan	3
4.	Looking back or double-checking	4

Data analysis was conducted descriptively and inferentially. Descriptive analysis used SPSS version 24 to calculate the mean, median, mode, standard deviation, minimum and maximum values. Inferential analysis included normality, homogeneity and hypothesis testing. Normality testing used the Statistical Package for Social Sciences (SPSS) version 22 system through the Shapiro-Wilk test at a significance level of a = 0.05. Data on scientific literacy and problem-solving skills will be normally distributed if the significance (2-tailed)> a and vice versa if the significance value (2-tailed) is less than or equal to a, then the sample is not normally distributed.

Homogeneity test using Statistical Package for Social Sciences (SPSS) system through Levene test at significance level a = 0.05. Data of communication skills, critical thinking skills and problem solving skills will be homogeneous if the significance (2-tailed) > a and vice versa if the significance value (2-tailed) is less than or equal to a, then the data is not homogeneous.

Hypothesis testing in this study aims to determine the differences in scientific literacy and problem-solving skills between students who follow the POGIL and direct instruction learning models in class XI of SMA Negeri 14 Gowa. The test was carried out using the ANCOVA test with the help of the SPSS Statistic 23 program. Decisions were taken based on a significance level of 0.05, where H_0 is accepted if the significance value is more than 0.05.

3. RESULT AND DISCUSSION

This research was conducted at SMA Negeri 14 Gowa with a quasi-experimental design using an experimental group (class XI A3, 30 students) that applied the POGIL learning model and a control group (class XI B2, 30 students) with a direct instruction model. The sample was selected non-randomly based on learning outcomes. The study aims to determine the effect of the POGIL model on students' scientific literacy and problem-solving skills. Data were analyzed using descriptive and inferential statistics to test the hypothesis.

1. Descriptive Statistical Analysis Results

a. Student science literacy results

The data obtained are the science literacy scores of class XI A3 and XI B2, each consisting of 30 students, who were taught using the POGIL model in the experimental class and the DI learning model in the control class. Seen in the following table:

Table 7. Results of Descriptive Analysis of Students' Scientific Literacy

Statistics	Science Literacy score of Learners			
	POGIL Model		DI Model	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Lowest score	11	44	11	44
Highest score	78	100	67	100
Average	42.83	77.97	42.53	68.40
Standard deviation	15,594	13,634	15,704	13,589
Number of Samples	30	30	30	30

Based on table 7 descriptive statistical analysis of the value*pretest*scientific literacy of students before implementing the POGIL learning model, it can be seen that the research sample consisted of 30 students with an average score of 42.83. While the average posttest score was 77.97. The average score of scientific literacy of students after being taught through the POGIL learning model increased with an average score of 77.97 with a sufficient category.

Mark*pretest*scientific literacy of students before implementing the DI learning model, it can be seen that the research sample consisted of 30 students with an average score of 42.53. While the average posttest score was 68.40 after implementing the DI learning model. The scientific literacy score of students after implementing the DI model increased with an average score of 68.40 in the low category. The average score in both classes increased, the class taught using the POGIL learning model had a higher average score compared to using the DI learning model. Frequency distribution, scientific literacy score categories can be seen in the following table:

Table 8. Frequency Distribution and Percentage of Students' Science Literacy Value Categories

Interval	Category	POGIL Model				DI Model			
		Pretest		*Posttest*		*Pretest*		*Posttest*	
		F	%	F	%	F	%	F	%
90-100	Very high	0	0.00	3	10.00	0	0.00	1	3.33
80-89	High	0	0.00	8	26.67	0	0.00	3	10.00
70-79	Simply	1	3.33	9	30.00	0	0.00	7	23.33
60-69	Low	3	10.00	7	23.33	3	10.00	9	30.00
< 60	Very Low	26	86.67	3	10.00	27	90.00	10	33.33
Amount		30	100%	30	100%	30	100%	30	100%

Information:
F : Frequency
% : Percentage

Based on table 8 Frequency distribution and percentage of value categories*pretest*The scientific literacy of students before implementing the POGIL learning model of 30 students obtained a picture, namely, no students were able to obtain the very high and high categories, 1 student obtained a score of 70-79 in the sufficient category with a percentage of 3.33%, 3 students obtained a score of 60-69 in the low category with a percentage of 10%, and 26 students obtained a score of 0-60 in the very low category with a percentage of 86.67%. Frequency distribution and percentage of posttest score categories of students' scientific literacy after applying the POGIL learning model to 30 students showed that 3 students were able to obtain scores of 90-100 in the very high category with a percentage of 10%, 8 students were able to obtain scores of 80-89 in the high category with a percentage of 26.67%, 9 students obtained scores of 70-79 in the sufficient category with a percentage of 30%, and 7 students obtained scores of 60-69 in the low category with a percentage of 10%, and 3 students obtained scores of 0-60 in the very low category with a percentage of 10%. The scientific literacy scores of the experimental class after being treated with the POGIL learning model increased. Of the 30 students who were the research sample, 27 students obtained scores in the very high, high, sufficient categories and only 3 people obtained very low scores.

Frequency distribution and percentage of value categories*pretest*scientific literacy of students before implementing the DI model of 30 students obtained a picture, namely, no students were able to obtain a very high, high, and sufficient category, 3 students obtained a score of 60-69 in the low category with a percentage of 10%, 27 students obtained a score of 0-60 in the very low category with a percentage of 90%. While the frequency distribution and percentage of the posttest value category of scientific literacy of students after implementing the DI learning model of 30 students obtained a picture, namely, 1 student was able to obtain a score of 90-100 in the very high category with a percentage of 3.33%, 3 students obtained a score of 80-89 in the high category with a percentage of 10%, 7 students obtained a score of 70-79 in the sufficient category with a percentage of 23.33%, and 9 students obtained a score of 60-69 in the low category with a percentage of 30% and 10 students obtained a score of 0-60 in the very low category with a percentage of 33.33%. Descriptive value of scientific literacy of control class students after being given treatment with DI learning model increased. This can be seen from the achievement of scientific literacy value before and after being given treatment.

Then for the analysis of each aspect of the scientific literacy indicator, namely understanding the inquiry method that leads to scientific knowledge with 4 multiple-choice questions and organizing, analyzing, and interpreting quantitative data and scientific information with 5 multiple-choice questions. The achievement of each scientific literacy indicator is presented in Figure 2 as follows:

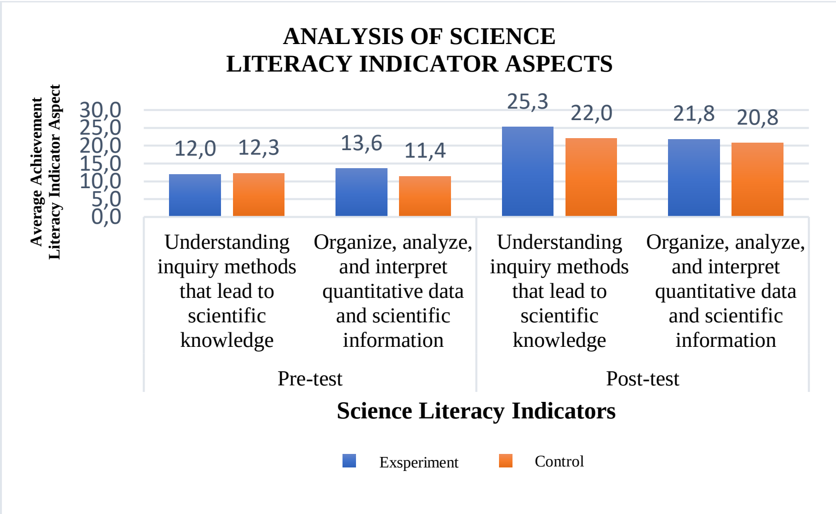

Figure 1.Comparison Chart of Pretest and Posttest Average Scores of Science Literacy

In the experimental class, there was a significant increase in the achievement of scientific literacy indicators from*pretest*to posttest. The average achievement in the indicator "understanding inquiry methods that lead to scientific knowledge" increased from 12.0 to 25.3. Likewise, the indicator "organizing, analyzing, and interpreting quantitative data and scientific information" increased from 13.6 to 21.8. This increase shows that the learning model applied is able to encourage active involvement of students in the learning process. Students not only receive information, but are also involved in the process of observation, analysis, and drawing conclusions independently. This makes them understand the concept of science more deeply and are able to relate it to real contexts.

In the control class, there was also an average increase, but not as large as in the experimental class. The average achievement of the indicator "understanding the inquiry method" increased from 12.3 to 22.0, and the indicator "organizing, analyzing, and interpreting data" increased from 11.4 to 20.8. Although there was an increase, the learning process in the control class which focused more on delivering information directly provided less space for students to explore and think critically independently. As a result, the development of scientific literacy in this class was not as strong as in the experimental class which implemented an active and student-centered learning approach.

b. Problem Solving Skills Results

The data obtained are the problem solving skills scores of classes XI A3 and XI B2, each of which consists of 30 students:

Table 8. Results of Descriptive Analysis of Students' Problem Solving Skills

Statistics	Science Literacy score of Learners			
	POGIL Model		DI Model	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Lowest score	38	68	38	63
Highest score	75	100	75	94
Average	56.90	85.97	56.13	77.63
Statistics	Science Literacy score of Learners			
	POGIL Model		**DI Model**	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Standard deviation	7,658	8,884	8,840	7,989
Number of Samples	30	30	30	30

Based on the table 8. Descriptive statistical analysis of the pretest value of problem-solving skills before implementing the POGIL learning model, it can be seen that the research sample consisted of 30 students with an average value of 56.90. While the average posttest value of students' problem-solving skills after implementing the POGIL learning model was 85.97 with a high category. The value of students' problem-solving skills after being taught through the POGIL learning model increased.

Mark*pretest*problem solving skills of students before implementing the DI learning model, it can be seen that the research sample consisted of 30 students with an average score of 56.13. While the average posttest score of students' problem solving skills after implementing the DI learning model was 77.63 in the moderate category. The value of students' problem solving skills after implementing the DI model increased. The average score in both classes, the class taught using the POGIL learning model had a higher average score compared to using the DI learning model. Frequency distribution, problem solving skill value categories can be seen in table 4.4 below.

Table 9. Frequency Distribution and Percentage of Student Problem Solving Skills Value Categories

Interval	Category	POGIL Model				DI Model			
		Pretest		*Posttest*		*Pretest*		*Posttest*	
		F	%	F	%	F	%	F	%
$80 \leq X \leq 100$	High	0	0.00	25	83.33	0	0.00	13	43.33
$60 \leq X < 80$	Medium	11	36.67	5	16.67	10	33.33	17	56.67
$X < 60$	Low	19	63.33	0	0.00	20	66.67	0	0.00
Amount		30	100%	30	100%	30	100%	30	100%

F : Frequency
% : Percentage

Based on the table 9. Frequency distribution and percentage of pretest value categories of students' problem solving skills before implementing the POGIL learning model of 30 students obtained a picture, namely, no students were able to obtain a high category, 11 students obtained a score of 60-79 in the medium category with a percentage of 36.67%, 19 students obtained a score of 0-60 in the low category with a percentage of 63.33%. Frequency distribution and percentage of posttest value categories of students' problem solving skills after implementing the POGIL learning model of 30 students obtained a picture, namely, 25 students were able to obtain a score of 80-100 in the high category with a percentage of 83.33%, 5 students were able to obtain a score of 60-79 in the high category with a percentage of 16.67%, and no students obtained a score of 0-60 in the low category. The problem solving skill scores of the experimental class after being treated with the POGIL learning model increased. Of the 30 students who were the research sample, 25 students obtained high category scores and 5 students obtained medium category scores, and no students obtained low scores.

Frequency distribution and percentage of value categorie s*pretes t*problem solving skills of students before implementing the DI model of 30 students obtained a picture, namely, no students were able to obtain a high category, 10 students obtained a score of 60-78 in the medium category with a percentage of 33.33%, 20 students obtained a score of 0-60 in the very low category with a percentage of 66.67%. While the frequency distribution and percentage of the category of posttest scores of students' scientific literacy after implementing the DI learning model of 30 students obtained a picture, namely, 13 students were able to obtain a score of 80-100 in the high category with a percentage of 56.67%, and no students obtained a score of d0-60 in the low category. Descriptive value of problem solving skills of students in the control class after being given treatment with the DI learning model increased. This can be seen from the acquisition of problem solving skills scores before and after being given treatment.

Then for the analysis of each aspect of the problem solving skills indicator, namelyunderstanding the problem (understanding), planning (planning), implementing the plan (solving), and reviewing (checking). The achievement of each indicator of problem-solving skills is presented in Figure 2 as follows:

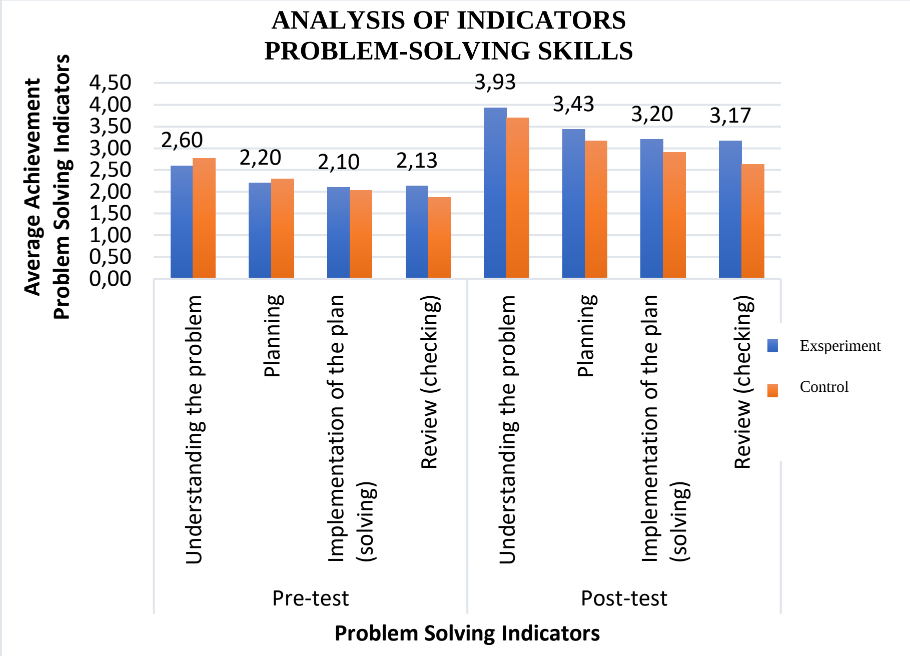

Figure 2**.** Comparison Chart of Pretest and Posttest Average Scores of Problem Solving Skills

On*pretest*experimental class, the average value of problem-solving skills of experimental class students ranged from 2.10 to 2.60 for all indicators. After the implementation of the POGIL learning model, there was a significant increase in the posttest. The indicator of understanding the problem experienced the highest increase, reaching an average value of close to 3.93, followed by planning, implementing the plan, and reviewing which were in the range of 3.17. This increase shows that a learning approach that involves active involvement and critical thinking, such as POGIL, helps students be more systematic in identifying, planning, and evaluating solutions to problems.

Average value*pretest*in the control class was slightly lower than the experimental class, which was between 1.87 and 2.77. At the time of the posttest, the increase still occurred, but not as strong as in the experimental class. The indicator of understanding the problem obtained the highest increase with an average approaching 3.70, while other indicators such as planning, implementing the plan, and reviewing increased moderately to reach 3.17–2.63. This shows that conventional learning is still able to support basic understanding, but is less than optimal in encouraging complex problem-solving skills as a whole.

2. Inferential Statistical Analysis

a. Normality Test

Normality test was conducted on data of science literacy results and problem solving skills in classes taught with the process oriented guided inquiry learning (POGIL) model and the direct instruction (DI) model. The normality test was used to determine whether the data was normally distributed or not, the results of the Shapiro-Wilk normality test on data of science literacy and students' problem solving skills on the pretest and posttest scores had a sig. value > 0.05 (significance value more than 0.05). So it can be concluded that the data of science literacy and problem solving skills are normally distributed.

b. Homogeneity Test

Homogeneity test data of the influence of the POGIL learning model on science literacy and problem-solving skills of students of SMA Negeri 14 Gowa. This test was conducted to determine whether the sample variances were the same or not. The homogeneity test was conducted as a prerequisite in conducting hypothesis analysis. If the samples have the same variance, then both are said to be homogeneous. The criteria for hypothesis testing are if the sig value ≥ a = 0.05 then statistically the two variances are the same or homogeneous.

The results of the homogeneity test of the data on the variables of scientific literacy and problem-solving skills of students in the pretest and posttest have a sig. value > 0.05 (significance value more than 0.05). So it can be concluded that the data on the variables of scientific literacy and problem-solving skills are homogeneous. After the prerequisite test is met, the next step is to conduct a hypothesis test using Analysis of Covariance (Ancova). The Ancova test aims to determine the effect of each independent variable on the dependent variable. In this Ancova test there are control variables or as covariates.

c. Hypothesis Testing

Hypothesis testing is conducted to answer the previously formulated hypothesis. The criteria for hypothesis testing are if the sig value (0.000 ≤ a = 0.05) then Ho is rejected and H is accepted or there is a difference in the scientific literacy of students who are applied to the process oriented guided inquiry learning (POGIL) learning model with direct instruction and there is a difference in the problem-solving skills of students who are applied to the process oriented guided inquiry learning (POGIL) learning model with direct instruction.

1. Hypothesis Test of Students' Science Literacy

The results of the scientific literacy hypothesis test show that the significance value obtained is 0.008. Referring to the hypothesis testing criteria if the significant value is (0.000 <a = 0.05) so that Ho is rejected and H1 is accepted or there is a difference in scientific literacy of students who apply the process oriented guided inquiry learning (POGIL) learning model with direct instruction of class XI students of SMA Negeri 14 Gowa.

2. Hypothesis Test of Students' Problem Solving Skills

The results of the problem-solving skill hypothesis test show that the significance value obtained is 0.000. Referring to the hypothesis testing criteria if the significant value is (0.000 <a = 0.05) so that Ho is rejected and H1 is accepted or there is a difference in the problem-solving skills of students who apply the process oriented guided inquiry learning (POGIL) learning model with direct instruction of class XI students of SMA Negeri 14 Gowa.

B. Discussion

1. The Influence of the Process Oriented Guided Inquiry Learning (POGIL) Learning Model on Students' Science Literacy

Based on the results of descriptive statistical analysis, students' scientific literacy after the application of the process oriented guided inquiry learning (POGIL) learning model in the experimental class showed a significant increase. The distribution of students' scientific literacy scores is as follows: 3 students (90–100, very high category), 8 students (80–89, high category), 9 students (70–79, sufficient category), 7 students (60–69, low category), and 3 students (0–59, very low category). Of the 30 students who were the research sample, most (20 students) obtained scores in the very high to sufficient category, while 7 students were in the low category and 3 students were in the very low category. With an average score of 77.97 (sufficient category).

However, the average score that is still in the sufficient category indicates that the increase in scientific literacy is not evenly distributed across all students. This can be associated with initial readiness and background knowledge that is not yet balanced, as explained by Bransford et al., (2000), that the learning process is highly dependent on students' initial knowledge. In addition, although POGIL requires active and collaborative involvement, not all students have strong independent learning skills or strong collaboration skills from the start (Moog & Spencer, 2008), which can limit the effectiveness of this model.

Other limitations also lie in the level of curiosity and cognitive engagement of students during the inquiry process. Wu et al.'s (2018) study showed that low curiosity can hinder the development of inquiry skills and scientific literacy. In addition, if learning support or scaffolding from teachers is not optimal, students tend to experience confusion in the exploration process (Hmelo Silver et al., 2007). Factors such as limited time allocation and high levels of material difficulty also strengthen the possibility that some students have not been able to optimize their potential in the context of inquiry-based learning.

Thus, although the implementation of the POGIL model has shown effectiveness in encouraging increased scientific literacy, the average results are still quite good, indicating that this approach needs to be accompanied by supporting strategies, such as strengthening independent learning skills, improving the quality of teacher facilitation, and enriching learning contexts that are adaptive to students' needs. However, the fact that most students achieved the category of sufficient to very high scientific literacy reflects that this model has succeeded in stimulating understanding of scientific concepts, critical thinking skills, and active involvement in learning. This is a positive indication that POGIL can be a strong foundation for the development of more equitable and in-depth scientific literacy, if balanced with continuous and targeted learning support.

Meanwhile, scientific literacy in the control class after implementing the Direct Instruction (DI) learning model showed the following results: 1 student (90–100, very high category), 3 students (80–89, high category), 7 students (70–79, sufficient category), 9 students (60–69, low category), and 10 students (0–59, very low category).

The average value obtained was 68.40. The low scientific literacy of students is caused by the teacher-centered learning model, so that the information obtained by students is limited and their active participation in the learning process is less than optimal.

According to Freeman et al. (2014), the traditional Direct Instruction model tends to limit active participation of students because learning is centered on the delivery of material from the teacher. Although it has been developed with small group activities (Stockard et al., 2018), learning is still dominated by the teacher, so students have limited space to explore ideas independently..

OECD (2018) emphasizes that the development of scientific literacy requires active involvement of students in reasoning, analyzing data, and connecting scientific concepts with real life. These skills are more effectively developed through inquiry-based learning models compared to direct learning, research by Wulandari et al. (2023) confirms that inquiry-based learning is more effective in improving scientific literacy than traditional methods. Therefore, although the DI used in this study facilitates group work, the focus of learning that remains on teacher instructions makes students less likely to develop critical and exploratory thinking skills optimally. In addition, according to Gormally et al. (2012) and Stockard et al. (2018), it also strengthens that inquiry develops more investigations of real phenomena and reflective discussions. This finding is in line with the results of this study, where the experimental class showed higher scientific literacy than the control.

Based on the results of the analysis of inferential data on scientific literacy of students in the experimental and control classes, it shows that there are differences in scientific literacy taught by the POGIL learning model and the DI model, in this case the POGIL learning model has an effect on scientific literacy. This is supported by the theory that POGIL is a constructivism-based approach, where students build their own knowledge through exploratory and collaborative activities in small groups (Farrell et al., 1999; Moog & Spencer, 2008). This approach allows students to be more active in the learning process, while developing critical thinking skills and the ability to understand and apply scientific concepts. Research by Widyaningsih et al. (2012) found that students who learned using POGIL showed a significant increase in scientific literacy, especially because they were trained to interpret data, connect scientific concepts with real phenomena, and discuss ideas reflectively. This is in line with the findings of this study, where students in the experimental class showed a higher average scientific literacy score than the control class.

POGIL provides a directed yet open-ended learning experience, with activities that stimulate scientific inquiry activities, such as observing, identifying patterns, analyzing data, and concluding, which are key indicators of scientific literacy (Gormally et al., 2012; Siahaan et al., 2021). In addition, small group discussions facilitate scientific communication and argument evaluation, which strengthen students' understanding and meaning of concepts (Straumanis & Simons, 2008). Apart from the cognitive aspect, scientific literacy is also influenced by motivation and learning independence. In the context of POGIL, students are given responsibility for their learning process, so that they become more interested, curious, and motivated to understand the material being studied (Wardany et al., 2023). Thus, the results of this study confirm that the POGIL learning model has a significant positive influence on scientific literacy, because it is able to create a learning environment that supports active participation, critical thinking, collaboration, and contextualization.

The results of the descriptive analysis showed that there were still 7 students in the low category and 3 students in the very low category. During the learning process, students were directed to work in small groups of 3-5 people. In each meeting, they were given inquiry-based LKPD that required them to analyze phenomena, formulate questions, seek information, and draw conclusions from the data or cases presented. However, based on class observations, students in the low and very low categories tended to be passive in group discussions, only following the flow formed by the more dominant group members. They rarely put forward opinions or questions, and were even seen only recording the final results without really understanding the thinking process being built in the group discussion. This is in line with the findings of Moog & Spencer (2008) which stated that the effectiveness of POGIL is greatly influenced by the active role of all members in the group. When participation is uneven, the learning experience of students becomes unequal.

Then, at the discussion and reflection stage, some students did not show significant development in terms of critical or reflective thinking. When asked to evaluate the group's hypothesis or review the conclusions of the activity, they tended to simply accept the group's answer without questioning the truth or proposing alternatives. This shows limitations in the metacognitive aspect, which according to Gunstone (1994), is an important foundation in the development of scientific literacy. Another thing identified during the learning process was the lack of motivation and self-confidence of some students. They seemed uncomfortable when asked to speak or explain the group's findings in front of the class. In the context of Ryan & Deci's (2000) self-determination theory, intrinsic motivation plays an important role in learning engagement and success. Students who feel insecure or do not see the meaning of the activities they do will tend to be less active and their learning outcomes will not be optimal.

The significant increase in the achievement of scientific literacy indicators in the experimental class shows the effectiveness of the learning model used, namely POGIL, in building students' scientific understanding. The increase in the value of the indicator of understanding inquiry methods that lead to scientific knowledge from 12.0 to 25.3 and the indicator of organizing, analyzing, and interpreting quantitative data and scientific information from 13.6 to 21.8 reflects that this approach is able to encourage students to be actively involved in the scientific inquiry process, not just passively receiving knowledge. This is in line with the findings of Bilgin (2009), which shows that integrated inquiry learning is able to improve students' conceptual achievement and positive attitudes towards the inquiry process. POGIL provides an activity structure that requires students to work in groups, analyze data, and build understanding through discussion and reflection. This strategy allows students to experience the scientific process directly as suggested by Moog & Spencer (2008), who stated that POGIL plays a role in improving high-level thinking and scientific skills.

On the other hand, although the control class also showed an increase, the increase was not as large as the experimental class. The increase from 12.3 to 22.0 and from 11.4 to 20.8 more reflects the effects of conventional learning which is information transmission in nature. This kind of learning, according to Areepattamannil et al. (2020), tends to reduce students' opportunities to develop scientific dispositions and critical thinking because the active role of students in exploring scientific ideas is limited. Furthermore, this finding is also supported by Furtak et al., (2012) in their meta-analysis which concluded that inquiry-based learning models, especially with scaffolding such as in POGIL, show a stronger positive effect on learning outcomes than traditional learning methods. Thus, the success of the POGIL model in improving scientific literacy is seen through the active role of students in the scientific inquiry process, group collaboration, and structured reflection in understanding and interpreting scientific phenomena.

2. The Influence of the Process Oriented Guided Inquiry Learning (POGIL) Learning Model on Students' Problem Solving Skills

Based on the results of descriptive statistical analysis of problem-solving skills after implementing the process oriented guided inquiry learning (POGIL) learning model in the experimental class, it showed a significant increase in average ability. This can be seen from the distribution of problem-solving skills scores, where 25 students scored 80–100 (high category) and 5 students scored 60–79 (medium category), and no students scored 0–59 (low category). Of the 30 students who were the research sample, most (25 students) were in the high category and 5 students were in the medium category. The average score obtained was 85.97, which is included in the high category.

Thus, this increase shows that POGIL is able to facilitate students' problem-solving skills effectively. This is in line with research by Ilma et al. (2024), which found that the POGIL model is effective in improving students' problem-solving skills. This is supported by classroom learning activities, where students work in small groups with structured roles such as manager, recorder, and presenter. Through the division of roles, students are invited to identify problems from the phenomena presented (for example, differences in breathing patterns during rest and after heavy activity), analyze data from the results of the practicum, and design solutions and conclude their findings. These stages reflect the steps of scientific problem solving in accordance with the theory of Smith et al. (2014), namely problem identification, plan formulation, implementation, and evaluation of solutions.

In addition, collaboration in group discussions and preparation of work reports allows students to develop critical thinking skills, scientific communication, and metacognition. Guner & Hatice (2021) stated that the POGIL model is effective in developing metacognitive skills, which are important in the process of reflecting and improving solutions that have been made. This is very evident when students hold reflective discussions at the end of learning to compare results between groups and relate them to the respiratory system theory that has been studied. Moog & Spencer (2008) also emphasized that in POGIL, problem solving occurs naturally because students are involved in the scientific thinking process, not just receiving information from the teacher. Therefore, active involvement in problem-based learning and concrete data makes students more prepared to face new situations, and able to make decisions based on evidence.

Meanwhile, problem-solving skills in the control class after implementing the learning model (DI) showed the following results: 13 students scored 80–100 (high category), 17 students scored 60–79 (medium category), and no students scored 0–59 (low category). The average score obtained was 77.63, which is included in the medium category. Although no students were in the low category, the average problem-solving skills of students in the control class were still below the experimental class. This condition is caused by the characteristics of teacher-centered learning, where the teacher is more dominant in providing information while students tend to be passive as recipients. The lack of student involvement in constructing knowledge and solving real problems causes problem-solving skills not to develop optimally.

However, although some students get quite good grades, the problem-solving skills in this class tend to be lower when compared to the experimental class using the POGIL learning model. This is understandable because the DI model tends to be more teacher-centered, where the teacher is the main source of information, while students are more passive in the learning process. In the DI model, students are given direct explanations by the teacher about certain concepts, followed by practice questions. This learning process reduces the opportunity for students to be actively involved in the problem-solving process. They are not given many opportunities to identify problems independently or develop their own solutions.

On the other hand, students receive more information from teachers, without much group discussion or investigation of real phenomena, which are very important for developing problem-solving skills. According to Freeman et al. (2014), more teacher-centered learning has a negative impact on active student engagement, which contributes to their low ability to think critically and solve problems. In this model, students focus more on memorizing and understanding basic concepts taught by teachers, but are less involved in collaborative activities that can develop critical thinking and problem-solving skills in more depth. This is in line with findings from the OECD (2018) which states that to develop problem-solving skills, students must be given the opportunity to analyze problems, find solutions, and connect the concepts learned with real-world phenomena.

The cause of low problem-solving skills in the control class, limitations in direct instruction are seen in the lack of active interaction of students. Students in the control class are not given many opportunities to discuss or collaborate in small groups to solve problems. They are also not invited to explore or solve problems based on direct observation and experience. In fact, according to Gormally et al. (2012), group discussions and scientific investigations are key to developing problem-solving skills. In addition, low intrinsic motivation of students also contributes to their limited involvement in learning.

Furthermore, to analyze the influence of the POGIL learning model on problem-solving skills in more depth, a review of the average score of each indicator before and after treatment in the experimental and control classes was conducted. The results of the analysis showed that the most significant increase occurred in the indicator of understanding the problem, with an average posttest score in the experimental class reaching 3.93 from an initial score of 2.10–2.60. This indicates that students are able to identify problems more clearly and precisely after participating in POGIL-based learning. In POGIL, the initial stages of learning activities are indeed designed to stimulate critical thinking and understanding of problematic situations through exploratory questions in groups (Moog & Spencer, 2008; Bransford et al., 2000). This is consistent with Wu et al. (2018), showing that direct inquiry experiences encourage greater curiosity and involvement in understanding problems. In contrast, in the control class, although this indicator also showed an increase (an average of 3.70), the achievement was not as high as the experimental class. This shows that conventional learning approaches are still able to foster basic understanding, but do not provide sufficient exploratory space to deepen problem identification (Areepattamannil et al., 2020).

Furthermore, the solution planning indicator also experienced a fairly high increase with an average reaching 3.17. In POGIL, planning activities are driven by collaborative thinking processes and scaffolding, so that students are able to develop problem-solving strategies logically and structured (Bilgin, 2009; van Uum et al., 2017). The plan implementation indicator showed a similar increase, indicating that active involvement in implementing solutions through discussion and simulation encourages students to be more responsible in implementing the plans that have been made (Trout et al., 2008).

Meanwhile, the review indicator showed the smallest but still significant increase, reaching an average of 3.17. This shows that students are beginning to be able to evaluate the solutions taken and show signs of reflective ability, although it still needs strengthening (Chinn & Duncan, 2021; Simonson & Shadle, 2013). This reflective ability is part of the high-level thinking skills that are an important component of scientific literacy (Reski, Daud, & Taiyeb, 2024). This reflective ability is an important part of the final stage in the problem-solving process, namely the evaluation of the solutions that have been implemented. According to Reski, Daud, and Taiyeb (2024), the success of problem solving is not only determined by the ability to analyze problems and formulate solutions, but also by the ability to evaluate the effectiveness of the solution. Research by Nasrun, Jumadi, and Palennari (2023) also revealed that students often have difficulty in critically reflecting on the results of their problem solving. Therefore, ongoing reinforcement strategies are needed, such as providing formative feedback and evaluative exercises, so that students can improve their reflective thinking skills and produce more effective solutions in the future.

In contrast to the experimental class, the increase in the control class was more moderate. The highest posttest average remained in the problem understanding indicator (around 3.70), but other indicators experienced unequal increases. For example, the review indicator only reached around 2.63, reflecting the limitations of the conventional approach in developing reflective and evaluative abilities. This indicates that although conventional learning still supports basic understanding, this model is less than optimal in developing comprehensive problem-solving skills, especially in the planning and evaluation aspects (Areepattamannil et al., 2020; Furtak et al., 2012). Thus, POGIL-based learning is proven to be more effective in developing all aspects of problem-solving skills.

4. CONCLUSION

Based on the results of the study and discussion, it can be concluded that the scientific literacy of students after the implementation of the Process Oriented Guided Inquiry Learning (POGIL) learning model is in the sufficient category, while problem-solving skills are in the high category. In contrast, students who are taught using the direct instruction model show scientific literacy in the low category and problem-solving skills in the moderate category. There is a significant difference between the scientific literacy and problem-solving skills of students who are taught using the POGIL and direct instruction models in class XI of SMA Negeri 14 Gowa.

The suggestions from this study are that the study was only conducted in one school and at the high school level, so it is recommended for further researchers to apply the POGIL model in several schools or at different levels. In addition, because the variables of this study are only focused on science literacy and problem-solving skills, it is recommended that the scope of the variables be expanded. Finally, because the implementation of POGIL was only carried out on the respiratory system material, further research is expected to test the effectiveness of this model on other materials or subjects to see the consistency of the results.

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