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The Effect of the POGIL Learning Model on High School Students' Problem Solving Abilities in Thermodynamics

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ABSTRAK. This research aims to describe the effect of the POGIL learning model on high school students' problem-solving abilities in thermodynamics. This model was chosen because it is a student-centered learning approach, which will facilitate students practice in problem-solving, particularly in thermodynamics. This type of research is a quasi-experiment with a quantitative approach and a one-group pretest-posttest design research. There are two classes used, namely the experimental class and the replication class. Both were given the same treatment to demonstrate the effect consistency. The sampling technique used convenience sampling. The sample size used was 55 students. Data collection techniques included interviews, questionnaires, and tests. Data analysis techniques used statistical tests, including n-gain test, normality test, homogeneity test, and hypothesis test. The n-gain test results indicate that the average n-gain of both classes falls within the middle criteria. Furthermore, the hypothesis testing results using the paired t-test show that H_1 is accepted (α <0,005). Both findings indicate that there is an effect of the POGIL learning model on the problem-solving abilities of high school students in thermodynamics. Meanwhile, the hypothesis testing using the independent t-test shows that H_1 is also accepted

1. Introduction

The Merdeka Curriculum emphasizes the development of critical thinking, creativity, communication, and collaboration skills, all of which are crucial components in the problem-solving process. Problem-solving ability is considered as one of the skills that needs to be mastered in facing the increasingly complex issues of the 21st century. (Kurniawati et al, 2019, p. 701). Problem-solving skills refer to the ability to organize one's knowledge to obtain solutions to a given problem. (Rahmawati & Ika, 2020, p. 162-163). Therefore, problem-solving skills are important for anyone to possess, including students. Problem-solving skills are closely related to life, as in real life, students will encounter problems that require the ability to find solutions as a way out. (Dewi et al., 2023). Students require problem-solving skills to make informed decisions, employing logical and systematic thinking, and being able to view problems from different perspectives (Herayanti et al., 2020, p. 960).

Physics learning is closely related to problem-solving. This is because the process of learning physics involves not only theory but also the application of that theory to solve real-life problems (Umamah & Andi, 2020). Furthermore, problem-solving skills are also utilized by teachers in teaching physics concepts and assessing students' abilities after learning (Riantoni et al., 2023). Despite the importance of problem-solving skills in physics learning, many students still lack proficiency in this area. The lack of understanding and mastery of physics concepts poses a hindrance to mastering problem-solving skills (Noviatika et al., 2019). When solving physics problems, students often directly use mathematical equations without first identifying the context of the problem. However, the ability to identify is crucial in solving physics problems (Gunawan et al., 2018). One of the physics concepts considered difficult for students to understand is thermodynamics. Most students struggle with concepts such as energy and entropy relationships, heat and temperature, and the laws of thermodynamics (Sutarja & Wulandari, 2021). Weak mastery of these concepts makes it difficult for students to solve problems related to thermodynamics (Miranda et al., 2023).

Based on interviews with two physics teachers at a school in Sidoarjo, it is evident that students have very low analytical and identification skills. Teachers also admit to the difficulty of teaching thermodynamics, especially the mathematical aspect. So far, the learning models used to train students' problem-solving skills are cooperative learning and peer tutoring. However, they have not been able to improve students' problem-solving skills. Additionally, 55% of students acknowledge that thermodynamics is difficult to understand. In conclusion, despite prior training in problem-solving skills, students still struggle to solve physics-related problems, particularly in thermodynamics. The suspected reason is that the learning models used have not been able to develop students' problem-solving skills, especially in thermodynamics. Therefore, a learning model that can enhance students' problem-solving skills is needed. One learning model believed to have the potential to develop problem-solving skills to the fullest extent is the Processed Oriented Guided Inquiry Learning (POGIL) model.

This learning model is based on constructivist philosophy, which can encourage active student learning through guided inquiry activities to solve problems (Pratiwi et al., 2019). There are three main stages in its implementation: exploration, concept discovery, and application (Prihatami, 2019). These activities help students construct their understanding and assist in developing their own knowledge (Memah et al., 2020). The stage with the most potential for developing students' problem-solving skills is the application stage, where students internalize previously constructed concepts through new problems or questions (Ardhana, 2020). The application of concepts to new problems is the process of problem-solving that emerges. Based on the above exposition, the purpose of this research is to describe the influence of the POGIL learning model on high school students' problem-solving abilities in thermodynamics.

2. Method

The type of research in this study is a quasi-experiment with a quantitative approach. The research design utilizes a one-group pretest-posttest design. Two groups are utilized: the experimental group and the replication group, each consisting of one class. Both groups receive the same treatment, which is the implementation of the

POGIL learning model. Table 1 illustrates the research design of the one-group pretest-posttest.

Table 1. One-Group Pretest-Posttest Research Design

Group	Prestest	Treatment	Posttest
Experiment	O_1	X	O_3
Replication	O_2	X	O_4

Source: Fraenkel, et al, 2012

Description:
O_1: pretest of experiment class
O_2: pretest of replication class
X: treatment
O_3: posttest of experiment class
O_4: posttest of replication class

Data collection was conducted during the second semester of the 2023/2024 academic year. The population in this study comprises all students in the XI Science class at Islamic High Schools in Sidoarjo, while the sample consists of students from classes XI Science 1 A and XI Science 1 B. Convenience sampling technique was employed, chosen based on the availability and ease of access of a group of individuals for research purposes (Fraenkel et al., 2012).

The independent variable in this research is the POGIL learning model. Implementation level of the POGIL learning model can be assessed through observation sheets. The minimum criteria for the implementation level of teaching is categorized as "good." Meanwhile, the dependent variable in this research is students' problem-solving abilities. The POGIL model is considered to have an effect on problem-solving abilities if: 1) the average n-gain of problem-solving abilities is at least in the middle category; and 2) a significant result is obtained through a t-test at $\alpha = 0.05$.

2.1 Implementation Procedure

The implementation procedure of the research can be illustrated in Figure 1.

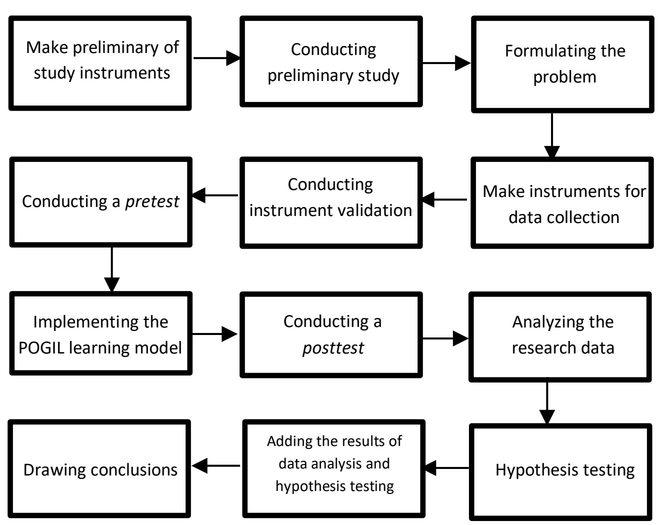

Figure 1. Research Implementation Procedure

2.2 Data Collection

The data collection methods included interviews, questionnaires, and tests. Interviews were conducted with two physics teachers using a semi-structured interview technique. Meanwhile, questionnaires and tests were administered to students.

2.3 Research Instruments

The instruments used include interview sheets and questionnaire sheets as pre-research instruments, teaching modules as treatment instruments, and learning implementation sheets and pretest-posttest questions as measurement instruments. Both the interview and questionnaire sheets contain questions or statements regarding classroom learning activities, physics materials, and students' problem-solving abilities. They have been constructively validated by two expert validators in their field. The teaching module consists of lesson plans (RPP) and student worksheets (LKPD). The validation results indicate that the developed instrumen is categorized as very high, with an Aiken's validity index of 0,92. The learning implementation sheet is in the form of an observation sheet aimed at determining the extent of the implementation level of learning using the POGIL model in thermodynamics material. The assessment data provided by the observer is then processed using Equation [1] and interpreted using the criteria in Table 2.

$$P = \frac{\text{The number of learning stages implemented}}{\text{The total number of learning stages}} \text{ x } 100\% \qquad (1)$$

Table 2. Criteria for Learning Implementation

Score (%)	Criteria
86 – 100	Very Good
76 – 85	Good
66 – 75	Fair
56 – 65	Poor
0 - 55	Very Poor

Source: Indah Paramita Alik et al, 2023

The pretest-posttest questions instrument consists of essay questions on thermodynamics material. The steps used to solve the questions follow Heller's problem-solving steps (1992), which include: 1) visualizing the problem; 2) describing the problem in the context of physics; 3) planning a solution; 4) implementing the solution plan; 5) checking and evaluating. Data on students' problem-solving abilities are obtained from test results using the scoring guidelines used by Gracia et al. (2018).

2.4 Data Analysis

The analyzed data consist of the validity score of the teaching module and the scores obtained from the pretest-posttest. The validity of the teaching module is determined using Aiken's V formula. Meanwhile, the pretest-posttest scores are statistically tested using n-gain test, normality test, homogeneity test, and hypothesis test. To test the n-gain, Equation [2] is utilized, then converted using the criteria in Table 3.

$$N - gain = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}} \text{ x } 100\% \qquad (2)$$

Table 3. N-gain Criteria

N-gain Score	Criteria
0,70 < *n-gain*	High
0,30 < *n-gain* < 0,70	Middle
n-gain < 0,30	Low

Source: Hasyim et al, 2020

The normality test is conducted using the Shapiro-Wilk test because the sample size used is close to 50 (Razali & Bee, 2011). The homogeneity test is conducted using the Harley test. Meanwhile, hypothesis testing is performed using the paired t-test and independent t-test. The paired t-test is used to compare the differences before and after treatment, while the independent t-test is used to compare the differences between the experimental and replication classes.

3. Result and Discussions

Both classes received the same treatment, which is the implementation of the POGIL learning model. Before and after the treatment, students completed a test consisting of essay questions on thermodynamics material. Table 4 shows the average pretest-posttest scores from both classes.

Table 4. Average of Pretest-Posttest

Class	$\sum$ Pretest	$\sum$ Posttest
Experiment	34,05	61,46
Replication	44,23	76,08

Based on Table 4, it is evident that there is an improvement in students' problem-solving abilities as indicated by the pretest and posttest scores. The average n-gain of both classes is shown in Table 5.

Table 5. Average of *N-gain*

Class	$\sum n - gain$	Criteria
Experiment	0,43	Middle
Replication	0,56	Middle

Based on Table 5, it can be observed that the average n-gain of both classes falls within the middle criteria. This serves as one indicator that the POGIL model has an effect on problem-solving abilities.

Before testing the hypothesis, normality and homogeneity tests were conducted first. The results of the normality test are shown in Table 6.

Table 6. Results of Normality Test

Class	Statistic	df	Sig.
Experiment	.944	28	.143
Replication	.959	27	.345

Since the significance value is >0.05, both classes are considered to have a normal distribution. Next, the homogeneity test is conducted by comparing the largest and smallest variances ($F_{calculation}$) then comparing them with F_{table}. The result of $F_{calculation}$ is 1,33, while F_{table} is 1,95. Since $F_{calculation} < F_{table}$, the data can be said to have identical variances and thus are homogeneous.

After ensuring that the data are normally distributed and homogeneous, hypothesis testing can be conducted. Hypothesis testing is performed using the paired t-test and independent t-test. The results of the paired t-test are shown in Table 7.

Table 7. Result of *Paired T-Test*

	Mean	Std Dev	95% Confid		t	df	Sig	
			Low	Upp			1 side	2 side
Pre-Post	-29,6	13,58	-33,27	-25,93	-16,2	54	0,000	0,000

Based on Table 7, the significance value (sig) is 0.000 < 0.05, indicating that there is a significant difference in students' problem-solving abilities before and after the treatment. This serves as another indicator that the POGIL model has an effect on problem-solving abilities. Furthermore, the results of the independent t-test are shown in Table 8.

Table 8. Result of *Independent T-Test*

		Levene's Test for Equality of Variances		*t*	*df*	*t-test for Equality of Means*	
						Significance	
		F	Sig.			*1 side*	*2 side*
PSA Result	Equal variances assumed	,979	,327	-2,807	53	,003	,007
	Equal variances not assumed			-2,798	50,932	,004	,007

Based on Table 8, the significance value (sig) is 0.007 < 0.05, indicating a significant difference in students' problem-solving abilities between the experimental and replication classes. This suggests an inconsistency in the effects between the experimental and replication classes. The occurrence of inconsistency is suspected to be caused by inconsistencies in the treatment during the research, one of which is the different durations of learning in the two classes. This is supported by the results, which show that the implementation of the treatment in the experimental class was 89%, while the replication class achieved a 94% implementation rate.

4. Conclusion

Based on the data and analysis conducted, it can be concluded that the POGIL learning model has an effect on high school students' problem-solving abilities in thermodynamics. There is an improvement in the problem-solving abilities of high school students after the implementation of the POGIL learning model. However, there is a lack of consistency in the effects observed on problem-solving abilities in students from the other class. The suspected cause of this inconsistency is the inconsistency in treatment during the research period. Similar research can be conducted by other researchers to verify the consistency of the effect.

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Author's Involvement

The author's involvement was carried out with IW guiding the research planning process and writing the article. HACW also assisted in research guidance. Meanwhile, AH carries out research data collection and processing.

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