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The Effect of the Process-Oriented Guided Inquiry Learning Model on Students' Problem-Solving Skills in the First Law of Thermodynamics

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Abstract: This study aimed to examine the effect of the Process-Oriented Guided Inquiry Learning (POGIL) model on students' problem-solving skills in the topic of the first law of thermodynamics. The research was motivated by pre-study findings showing students' struggles in identifying problems and applying solutions, partly due to limited stimulation in developing critical thinking and inquiry skills. A quasi-experimental method with a nonequivalent control group design was used. The population included 168 Class XI Science students at SMA Negeri 4 Tasikmalaya, with purposive sampling selecting two classes as experimental and control groups. Data were collected using pretests and posttests comprising eight essay questions assessing four stages of problem-solving: identifying problems, planning solutions, implementing solutions, and evaluating results. Hypothesis testing (t_{test}) at a 95% confidence level showed $t_{count} > t_{table}$ (9.78 > 1.67), confirming a significant positive effect of the POGIL model. The findings indicate that the POGIL model effectively enhances students' problem-solving skills, particularly in identifying problems, formulating hypotheses, and analyzing solutions. However, its implementation requires adequate preparation and teacher understanding of its stages. These results suggest that POGIL is a promising approach to fostering critical thinking and problem-solving skills in physics education.

Keywords: First law of thermodynamics; POGIL model; Problem-solving skills

Introduction

Physics and problem solving are two things that cannot be separated. One of the goals of the Physics learning process is to create individuals who are able to solve complex problems by implementing their knowledge and understanding in everyday situations (Walsh in Sujarwanto et al., 2014). In the Physics learning process, problem solving skills are very important for students because problem solving principles can help students build new knowledge and make learning Physics easier (Mukhopadhyay, 2013). Problem solving is an encompassing skill ability to search for information, analyze situations and identify problems by generating alternative goals resulting in decisions can be taken to achieve goals (Asrizal et al., 2023). Face challenges of the 21st century, teachers should prepare their students to become investigator, problem solver, critical and creative thinker (Herawati & Wilujeng, 2023). Apart from that, students can have the ability to understand something concepts to be able to make the right decisions (Suryadi et al., 2023). Students' skill to solve problems is one measure of success student (Selviyana et al., 2022).

Problem analysis has been carried out using several methods, including conducting interviews with Physics

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teachers, observing Physics teaching and learning activities, and testing students' initial problem-solving skills. Based on an interview with a physics teacher, the First Law of Thermodynamics is considered one of the most challenging topics for students to grasp due to its abstract nature, which often causes confusion in understanding its concepts. This causes students to fail to understand the core ideas of the subject. The learning model used by teachers in teaching physics in class is Problem Based Learning and Guided Inquiry. From these problems, a physics learning model is needed with use more learning models varied and centralized learning process on students can make students play an active role in the learning process (Sanggara et al., 2018).

Based on the results of observations of Physics teaching and learning activities in class, information was obtained that the Problem Based Learning and Guided Inquiry models had not been implemented optimally because teachers still predominantly used the lecture method. Often method conventional learning is still the main choice in teaching (Novitha & Suhartini, 2023). Another problem is that students do not participate actively in physics learning because the teacher is still the center of learning.

Students' initial problem-solving abilities were tested to obtain more accurate data. From the results of students' initial problem-solving skills tests, the percentage results of the average score are presented in Table 1.

Table 1. Percentage of initial problem-solving skills test results

Stage	Percentage (%)	Category
Understanding the problem	44.4	Less
Planning a strategy	22.2	Less
Implementing the strategy	59.6	Less
Evaluating solutions	58.6	Less

Based on the information in Table 1, it is known that it is still in the poor category at the stages of understanding the problem, planning strategies, implementing strategies, and evaluating solutions. So, students' problem-solving skills in the First Law of Thermodynamics still need to be improved.

One way to overcome students' low problem-solving skills is to apply the POGIL model in Physics learning. According to Rege in Moog & Spencer (2008), the POGIL model is a collaborative-constructive learning model that uses guided inquiry in a structured cycle of exploration, concept discovery and application. The POGIL learning model is important to be applied because in activities POGIL works in a team form so that inquiry activities are guided can be used to develop understanding and questions, solutions individual problems and responsibilities (Rustam et al., 2017). The POGIL model is predicted to be able to overcome students' problem-solving ability standards because the POGIL model requires students to actively participate in learning to gain knowledge by developing skills during the learning process, one of which is problem solving skills. This is also supported by Rosidah (2013) which states that students' problem-solving abilities in learning using the Process-Oriented Guided Inquiry Learning (POGIL) model assisted by Student Activity Sheets (LKPD) are higher than those of students without this approach. POGIL learning sequence has five stages including the Orientation Stage, stage exploration, concept formation stage, application, and closing stage (Hidayah et al., 2023).

Apart from that, in the POGIL model students have their own roles in groups so that students can express themselves and express their opinions in learning. Based on the factual problems that have been raised, this research was designed with the aim of improving students' problem-solving skills by applying the POGIL model to the First Law of Thermodynamics in class XI Science. It is hoped that this research can have a positive impact contribution to improving the quality of Physics learning in Class XI SMA, especially at SMAN 4 Tasikmalaya.

Method

This research was conducted at SMA Negeri 4 Tasikmalaya. The research subjects were students of class XI Science at SMA Negeri 4 Tasikmalaya with a population of 5 classes of 168 people. Researchers used purposive sampling to collect data samples, where groups of individuals or classes were selected with certain considerations (Sugiyono, 2017). Research data was collected through interviews, observations, and initial tests of students' problem-solving skills. The initial test of students' problem-solving skills is aimed at testing students' abilities in the four stages of problem-solving skills including understanding problems, planning strategies, implementing strategies, and evaluating solutions (Polya, 1985).

This research uses a quasi-experimental method which aims to determine the cause and effect between one variable and another. This design involves two groups: an experimental group and a control group. The experimental group was treated with the POGIL model, and the control group used a learning model commonly applied in schools, namely the Problem Based Learning model. The research design used is Nonequivalent Control Group Design, where the control and experimental groups are selected through certain considerations so that the homogeneity between groups is almost the same. Before carrying out the field test, the

test instrument for students' initial problem-solving skills was validated by experts and then calculated using content validity and reliability tests. The field test was carried out to measure students' problem-solving skills with an instrument in the form of 8 numbered descriptive questions. Prerequisite tests, namely normality tests and homogeneity tests, are carried out to determine whether the data collected is normally distributed and proven to be homogeneous or not (Sugiyono, 2019). After the data is proven to be normally distributed and homogeneous, the final test step is hypothesis testing (t test) to find out whether the POGIL model can influence improving students' problem-solving skills or not (Arikunto, 2012).

Result and Discussion

The results of research on the application of the POGIL model to students' problem-solving skills are presented in the form of tables and bar charts which are then narrated. This data was taken based on the results of the pretest scores and posttest scores which were carried out in the experimental and control classes.

The presentation of research results begins with a prerequisite test which includes normality and homogeneity tests. This test was carried out after data was collected from the pre-test scores and post-test scores of students in the experimental and control classes. The Chi-Square test at a significance level of 5% was carried out to determine whether the research data followed a normal distribution. Table 2 below displays the results of the research normality test.

Table 2. Chi-Square normality test results

Data	x^2_{count}	x^2_{table}	Conc.	Conc. Analysis
Pretest Exp. Class	4.52	12.8	H_0 accepted	The sample is taken from a normally distributed population
Pretest Cont. Class	5.50			
Posttest Exp. Class	4.11			
Posttest Cont. Class	2.44			

The F test, set at a significant level of 0.05, was used to test whether there was a significant difference between the pre-test and post-test scores for the experimental group and the control group. Table 3 below displays the results of the homogeneity test analysis.

Table 3. Fisher homogeneity test results

Data	F_{count}	α	F_{table}	Conc.	Conc. Analysis
Pretest Exp. Class	1.09	0.05	1.84	H_0 accepted	All variance is homogeneous
Posttest Exp. Class	1.62				

The data from the two samples were found to be normally distributed and of homogeneous variance after undergoing the prerequisite tests. Therefore, the t-test can be used to continue testing hypotheses. Table 4 displays the statistical analysis of the t-test findings for testing hypotheses.

Table 4 shows that t-count > t-table, where 9.78 > 1.67, from the free sample t-test at a significant level (α = 0.05), meaning that H0 is rejected or Ha is accepted. At the 95% confidence level, it can be said that the POGIL model affects students' ability to solve problems involving the first law of thermodynamics. This is in accordance with what Putri (2020) stated that the Process Oriented Guided Inquiry Learning (POGIL) model can improve students' problem-solving skills.

Table 4. Free sample *t-test* results

Data	t_{count}	α	t_{table}	Conc.	Conc. Analysis
Posttest score	9.78	0.05	1.67	H_a accepted	There is the effect of the POGIL model on students problem-solving skills in the first law of thermodynamics

The POGIL model applied to the experimental class, namely class XI IPA 1, influences students' problem-solving skills in the first law of thermodynamics. This influence is because the POGIL model stimulates or stimulates students' thinking abilities from the orientation stage to the closing stage, so that students are more systematic in identifying a given problem and it is easier to find a solution. According to Hasanah et al. (2023), the POGIL model is an inquiry learning model that is student-centered and based on the development of reasoning by providing questions and answers simultaneously. This is in line with the opinion expressed by Syafei & Mawardi (2022) that the POGIL model is a learning model that is able to involve students' active role, and motivate students to build meaning and develop deep understanding in each student. Learning requires students to actively participate in the process of discovering concepts and solving science-based problems. This is because through the POGIL Model students are more focused on determining problem solving which produces new concepts for students (Alvina et al., 2022). The POGIL learning model provides space for students to be active in cooperative learning activities. In accordance with the opinion expressed by Septianti et al. (2022) that the POGIL Model is based on constructivist principles which can make students more active through group interaction as problem solving. Apart from that, the POGIL learning model can improve and develop students' learning activities through experimental

activities so that students can exchange opinions and provide solutions to each other to solve problems through discussions so that students' problem-solving abilities are better trained. In accordance with the opinion of Lestari et al. (2019) that through the POGIL model students have a good opportunity to learn when they are active and involved in class and laboratory, discussing ideas, analyzing data, working together in groups to solve problems. According to Devi et al. (2019), applying the POGIL model in learning can develop students' problem-solving abilities and increase individual responsibility.

Figure 1 below compares the posttest average scores of the experimental class using the POGIL model and the control class using the PBL model. It shows that the average posttest scores of the experimental group are higher than those of the control group. In this experiment, a score of 64 is considered perfect. Using the POGIL model, the experimental group averaged 50.31 on the problem-solving skills posttest, while the control group scored 37.25. Based on these findings, the experimental group performed better on the posttest than the control group.

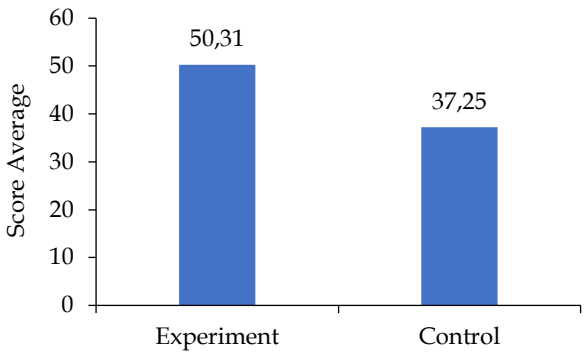

Figure 1. Comparison of the KPM average posttest scores of students in the experimental class and the control class

The N-Gain value data of the experimental class (applying the POGIL model) is 0.67, while the N-Gain value of the control class (applying the PBL model) is 0.35, providing further evidence that the application of the POGIL model to learning is practical for increasing students' Physics problem-solving skills. Students in both the experimental class (where the POGIL model was implemented) and the control class (where the PBL model was implemented) benefited from the experience. However, the POGIL model produced significantly better results.

The difference in the posttest results is due to the learning process in the experimental class using student-centered learning where in group discussion activities each student is given an envelope containing the role and is embedded in the group, the tasks and roles of each student in the group between the manager on duty as group manager, the reader serves as a reader of group activities, the recorder serves as a recorder of important aspects in the group discussion, and the reflector serves as an observer of group dynamics. This division of roles and tasks makes discussions more focused and active because students have the responsibility to carry out tasks according to their respective requests, besides that students can explore themselves more widely in finding a physics concept related to the problem. This is in accordance with the opinion of Mukin et al. (2024) that the roles given to each student in each group are carried out to make it easier for students to understand concepts, instill a spirit of responsibility in expressing themselves, and students do not rely on their group friends who have greater abilities. Students form teams and have their own roles in the team (Utari et al., 2023). The POGIL model provides students with a positive role in team success (Vanags et al., 2013). Another advantage of the POGIL model is that students train to have a confident, responsible attitude towards themselves and others. This is in accordance with the opinion of Hidayati & Listyani (2010) that the application of the POGIL model in the learning process towards student learning independence is drilled into creating an independent attitude towards others, having self-confidence, having discipline, having a sense of responsibility, acting on their own initiative, and practice self-control. The opinion expressed by Purtadi et al. (2023) is that the application of POGIL can also improve students' argumentation skills.

Meanwhile, the learning process in the control class also uses student-centered learning, but students in each group do not have their own roles and tasks, resulting in some students actively discussing, while others are just silent and quite a few students do not participate in the discussion. groups and group discussions become passive. This is in line with the opinion of Fakhriyah (2014) that applying the PBL model to learning requires independent learning activities for each student, and sometimes there are some students who rely on their group friends. The PBL model is a model that provides problems related to students' daily lives, then students in groups look for alternative solutions to these problems (Qotrunnada & Prahani, 2022). A similar opinion was expressed by Permata et al. (2022) that the application of the PBL model can provide space for students to be active and independent in assembling knowledge. Another reason the POGIL model is superior is because students discover concepts in their own way so that learning is more meaningful. This is in accordance with the opinion of Lestari et al. (2019) that the POGIL model helps students to discover their own knowledge. The POGIL model can also improve learning skills including thinking, problem solving,

teamwork, communication and management. This is in line with the opinion expressed by Johnson (2011) that the POGIL model in learning can develop and train students' thinking potential, one of which is in solving problems.

Based on the research discussion, applying the POGIL model is effectively used in Physics learning in the first law of thermodynamics in class XI Science at SMA Negeri 4 Tasikmalaya. These results are proven by the average posttest score and the percentage of the average posttest score from each stage of problem-solving ability by applying the POGIL model which is higher than the average posttest value and the percentage of the average posttest score from each stage of problem-solving ability by applying PBL model. This is in accordance with Putri (2020) opinion that the Process Oriented Guided Inquiry Learning (POGIL) model can improve students' problem-solving skills.

Conclusion

This study is quantitative research aimed at determining the effect of the POGIL model on students' problem-solving skills. The results concluded that the application of the POGIL model in physics instruction, particularly in the First Law of Thermodynamics, improves students' problem-solving abilities and fosters student-centered, active learning. This is evidenced by the hypothesis test results and the increase in the average test scores between the pre-test and post-test in the experimental class that implemented the POGIL model.

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Conceptualization, K. N. I., R. M., E. S.; methodology, E. S.; validation, R. M.; formal analysis, E. S.; investigation, K. N. I.; resources, K. N. I.; data curation, R. M: writing—original draft preparation, K. N. I.; writing—review and editing, R. M., and E. S.: visualization, K. N. I. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The author declares no conflict of interest.

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