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The Effect of the Modified Free Inquiry Learning Model on Students' Science Process Skills in Static Fluids

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ABSTRACT

This study aims to determine the effect of implementing the Modified Free Inquiry learning model on senior high school students' science process skills in the topic of static fluids at SMA Negeri 1 Telukjambe, Karawang Regency, in the 2025/2026 academic year. The study employed a quasi-experimental research method using a nonequivalent control group design, with class XI 2 as the experimental group and class XI 5 as the control group. The research data were collected using a test instrument in the form of eighteen multiple-choice questions. The N-gain analysis results indicate a higher improvement in science process skills in the experimental group, with an N-gain value of 0.64, compared to the control group, which obtained an N-gain value of 0.25. Based on these findings, it can be concluded that the implementation of the Modified Free Inquiry learning model is effective in improving students' science process skills in the topic of static fluids.

1. INTRODUCTION

Physics is one of the subjects that is considered quite difficult and challenging for students. Research shows that, based on questionnaire results, 33% of students stated that physics is a challenging subject and 51% reported that physics is difficult to understand (Azizah et al., 2015). Difficulties arise because physics concepts are abstract and difficult to implement concretely (Sari et al., 2022). Among various physics concepts, students find static fluids are difficult concept to comprehend (Novianto & Masykuri, 2018) . Static fluids concept includes topics such as hydrostatic pressure, Archimedes' principle, viscosity, and surface tension. This difficulty is caused by the limitations of teaching methods that focus primarily on direct information delivery. Physics learning does not only emphasize formulas but also how students understand concepts through direct learning experiences, so that the understanding they gain becomes more meaningful (Arifuddin et al., 2022).

Science process skills are a set of basic standard skills that must be possessed by students during science learning, particularly in physics, to understand, construct, and independently apply scientific concepts (Angelia et al., 2022; Gizaw & Sota, 2013; Triani et al., 2023). These skills include the abilities to observe, formulate problems and hypotheses, design experiments, collect and analyze data, and draw logical conclusions (Jurečková et al., 2024). Science process skills not only support the achievement of learning outcomes but also serves as an essential provision for facing the challenges of the 21st century, which require evidence-based problem solving.

Many students have not yet developed adequate science process skills due to the use of conventional teaching methods (Yetri et al., 2019). Conventional teaching method dominated by teacher-centered learning often make students passive, which ultimately has a negative impact on their conceptual understanding and science process skills (Hadi et al., 2018). Based on Hasanah & Prayogo (2023), other negative impacts of conventional teaching methods are low levels of student engagement and poor understanding of the subject matter in the classroom. Science process skills education in Indonesia is still considered to be at a low level, as reported by Rosalina et al. (2023), found that 5% of students were in the fair category, 16% were in the less good category, and 79% were in the poor category. Students' science process skills are still predominantly in the poor category because they have not been adequately trained through laboratory activities and observations, and teachers still frequently use direct instruction in the teaching process by Rosalina et al. (2023).

To help improve students' science process skills, an active science learning model is needed, particularly in the topic of static fluids, one of which is the Modified Free Inquiry (Barus et al., 2024). Modified Free Inquiry was developed as a learning model that emphasizes students' independence while still providing limited teacher support at key stages, such as problem identification and experimental design (Eristya & Asnam, 2019). This learning model gives students the freedom to seek information, ask questions, and conduct experiments independently; therefore, it is expected that students can develop their science process skills more effectively.

Modified Free Inquiry was introduced by Sund & Trowbridge (1973) and represents a development of inquiry-based models, including inquiry, guided inquiry, and structured inquiry. Modified Free Inquiry is an inquiry-based learning approach in which a problem or topic is provided as an initial stimulus, and students are given the freedom to design their own investigation procedures, experiments, and analysis processes. Modified Free Inquiry has the characteristic that teachers limit the amount of guidance provided so that students are encouraged to be more independent in finding solutions to problems. Therefore, the guidance given by the teacher should take the form of questions that stimulate students to think and determine appropriate investigative steps. Teachers pose questions that guide students toward problem solving rather than explaining what actions should be taken (Pratiwi, 2014).

From previous studies, it has been shown that Modified Free Inquiry model is effective in increasing students' creativity and conceptual understanding in science learning. However, most of these studies have examined the application of the Modified Free Inquiry model to science process skills in biology learning. Therefore, this study investigates the effect of the Modified Free Inquiry model on students' science process skills in static fluids. This study aims to determine the effect of the Modified Free Inquiry model on improving students' science process skills in static fluids.

2. METHODS

The research method used in this study is a quasi-experimental design. A quasi-experiment is a method that involves a control group but does not fully control all external variables that may influence the research (Sugiyono, 2019). This study implements the Modified Free Inquiry model with the aim of obtaining a deeper understanding of students' science process skills. The research employs a nonequivalent control group design. In this design, both the experimental and control groups are not selected randomly. Before the implementation of the treatment, students are given a pretest to determine their initial abilities. After the treatment is applied, both groups take a posttest to measure the level of students' science process skills in each group after receiving different treatments.

Table 1. Non Equivalent Control Grup Research Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_2
Control	O_1	X_2	O_2

Description:

X_1= Model *Modified Free Inquiry*
X_2 = Model *problem based learning*
o_1 = Pretest before treatment
o_2 = Posttest before treatment

This study involved 72 students who were divided into two groups, namely the experimental class and the control class. Data collection was conducted at a senior high school in Karawang Regency. The experimental class consisted of 36 students, while the control class also consisted of 36 students. The study was carried out with eleventh-grade students using a pretest and posttest design to measure students' science process skills.

The instrument used in this study was a science process skills instrument that covered ten indicators according to Rustaman et al. (2005), namely: (1) observing, (2) classifying, (3) interpreting, (4) predicting, (5) asking questions, (6) formulating hypotheses, (7) designing experiments, (8) using tools and materials, (9) applying concepts, and (10) communicating. However, in its implementation, the indicator of using tools and materials was not included because it was part of the direct observation activities carried out by the students. The instrument consisted of 18 multiple-choice questions. The data analysis techniques used in this study included:

a. **Normality**

This test used the Shapiro–Wilk test assisted by SPSS 26 software to determine whether the control and experimental groups were normally distributed or not (Pramesti, 2015).

b. **Homogeneity Test**

The homogeneity test is an evaluation conducted on the research subjects (the experimental and control classes) to determine whether they have similar data variance (homogeneous) or not. In this study, the homogeneity test was carried out using Levene's test (Nuryadi et al., 2017).

c. **Hypothesis Testing**

The next step is to conduct hypothesis testing based on specific criteria. If the population data are normally distributed and homogeneous, hypothesis testing is performed using parametric statistics. Conversely, if the data are not normally distributed and not homogeneous, hypothesis testing is conducted using nonparametric statistics (Patil, 2012).

d. **N-Gain Test**

The N-Gain test in this study was used to identify the improvement in results after the treatment was given to both the control and experimental classes. The calculation used the N-Gain formula (Hake, 1998):

$$N - gain = \frac{skor\ posttest - skor\ pretest}{skor\ ideal - skor\ pretest}$$

Table 2. N-Gain Category Criteria

Claification	Category
< 0.3	Low
$0.3 - 0.7$	Moderate
> 0.7	High

e. **The implementation analysis Modified Free Inquiry**

The analysis includes observations of the number of students who responded and the number of students who gave less accurate answers in each learning activity using student worksheet. The implementation analysis was conducted using the following formula (Widoyoko, 2009):

$$\%Skor = \frac{n}{N}\,100\%$$

Table 3. Percentage Categories of Learning Implementation

No	Percentage (%)	Category
1.	81 ≤ ×≤ 100	Very good
2.	61 ≤ ×≤ 80	good
3.	41 ≤ ×≤ 60	Adequate
4.	21 ≤ ×≤ 40	Poor
5.	0 ≤ ×≤ 20	Very Poor

3. RESULT AND DISCUSSION

3.1 Results

The research conducted examined the effect of the Modified Free Inquiry learning model on students' science process skills in the topic of static fluids at SMA Negeri Telukjambe. The total sample in this study consisted of 72 students divided into two classes, each containing 36 students. Class XI 2 served as the experimental class, while class XI 5 functioned as the control class.

3.1.1 Validity Test by Expert

The validity test in this study involved several experts who evaluated the research instrument based on several aspects. The instrument validation covered three main aspects, namely construct, content, and language.

Table 4. Validity Test Result

Aspect	CVI Score	CVI Category
Construct	0.98	Valid
Content (Material)	0.96	Valid
Language	0.99	Valid

From the table, those aspects showed a valid result. Therefore, it can be concluded that the test instrument is valid and can be used in reliability test.

3.1.2 Reliability Test

Reliability refers to the degree of consistency or trustworthiness of a measurement result. Reliability testing is conducted to ensure that the research instrument used to collect data is consistent and relevant to the objectives of the study. Method used in this testing was the Cronbach's Alpha formula.

Table 5. Reliability Test

Statistic	Reliability
r_{11}	0.76
Interpretation	High

3.1.3 Item Difficulty Index

Item difficulty index indicates the difficulty of each test item.

Table 6. Item Difficulty Index Result

Interpretation	Item Number	Total
Easy	1,3,6,7,8,9,10,11,12,13,15,17,18	13
Moderate	2,4,5,14,16	5
Difficult	0	0
Total		18

3.1.4 Discrimination Index

The item discrimination index refers to the ability of a test item to differentiate between students with high ability and low ability. A higher discrimination index indicates that the test item is better able to differentiate between students who have mastered the competencies and those who have not.

Table 7. Discrimination Index Result

Interpretation	Item Number	Total
Poor	-	0
Fair	1,3,7,8,9,10,11,12,13,14,15,16	12
Good	2,20	2
Very Good	5,6,7,17	4
Total		18

3.1.5 Improvement of Science Process Skills

The improvement of students' science process skills in both classes was determined using the average N-Gain score. The N-Gain results for the control class and the experimental class can be seen in the following table.

Table 8. Overall N-Gain Score Results

Class	N-Gain	Remarks
Control	0.25	Low
Experimental	0.64	Moderate

In the experimental class, there was an improvement in students' science process skills with an N-Gain score of 0.64, which falls into the moderate category. Meanwhile, the control class showed an improvement of 0.25, which is classified as the low category.

3.1.6 Improvement of Science Process Skills Indicators

There was an improvement in students' science process skills indicators in both groups, which can be observed in the following N-Gain test table.

Table 9. N-Gain Results of Science Process Skills

Indicators of Science Process Skills	N-Gain	
	Control class	Experimental Class
Observation	0.40	1.00
Classification	0.50	0.72
Interpretation	0.20	0.59
Prediction	0.11	0.72
Questioning	0.53	0.62
Formulating Hypotheses	0.20	0.59
Planning Experiments	0.60	0.68
Applying Concepts	0.14	0.72
Communicating	0.23	0.73

Based on **Table 5** of the Science Process Skills indicators, the N-Gain scores of the experimental class were generally higher than those of the control class across almost all indicators. The most significant improvements were observed in the indicators of observing (1.00 in the experimental class and 0.40 in the control class), predicting (0.72 and 0.11), applying concepts (0.72 and 0.14), and communicating (0.73 and 0.23). These results indicate that learning in the experimental class was more effective in improving students' science process skills compared to the control class.

3.1.7 Results of the Analysis of Modified Free Inquiry Learning Implementation

The observed implementation of the learning process included the application of the modified free inquiry model in static fluid material conducted over four meetings. The following table presents the percentage results of the learning implementation.

Table 10. Modified Free Inquiry Learning Implementation

Learning Phases	Session				Average Percentage	Category	Overall
	1	2	3	4			
Problem Orientation	83%	100%	67%	67%	79%	Baik	81%
Problem Formulation	83%	100%	83%	83%	87%	Sangat Baik	
Hypothesis	67%	83%	83%	83%	79%	Baik	
Data Collection	67%	83%	67%	67%	71%	Baik	
Testing the Hypothesis	67%	100%	100%	83%	88%	Sangat Baik	
Conclusion	100%	100%	67%	67%	84%	Sangat Baik	

The implementation of learning using the modified free inquiry model in each session showed good results. The overall percentage obtained an average score of 81%, which falls into the very good category.

3.1.8 Normality Test

The normality test used the pretest and posttest scores from both the experimental class and the control class. The Shapiro–Wilk test was applied to conduct the normality analysis.

Table 11. Normality Test Results of the Control and Experimental Classes

Science Process Skills	Class	Sig.	Shapiro-Wilk	Conclusion
df	36	36	36	36
Pretest	Experimental	0.332	Sig. > 0,05 = H_0 accepted	Normal Data
	Control	0.138		
Postest	Experimental	0.99	Sig. > 0,05 = H_0 accepted	Normal Data
	Control	0.64		

All significance values were greater than 0.05; therefore, H_0 was accepted. Thus, it can be concluded that the pretest and posttest data in both the experimental and control classes were normally distributed.

3.1.9 Homogeneity Test

This test was conducted using two groups, namely the experimental and control classes, based on the pretest and posttest data. The analysis was carried out using SPSS software. The results of the homogeneity test are presented in the following table.

Table 12. Results of the Homogeneity Test

Levene Statistic	Pretest	Posttest
Signifikansi	0.163	0.91
a	0.05	0.05
Decision	Homogen	Homogen

The results of the homogeneity test using the Levene's Statistic showed that the significance value for the pretest was 0.163 and for the posttest was 0.91. Both significance values were greater than the significance level of 0.05 (Sig. > 0.05); therefore, H_0 was accepted. Based on the normality and homogeneity tests, it can be concluded that the pretest and posttest data of both the control and experimental classes were normally distributed and homogeneous.

3.1.10 Paired sample t-test

Table 13. Paired Sample t-Test Results

Paired Sample t-test	Experimental Group	Control Group
Rata-Rata (Mean)	31.833	11.028
t (df)	11.607	7.426
Sig. $(2-tailed)$	0.000	0.000
Conclusion	H_1 accepted	

Based on the results of the paired sample t-test, the average improvement in the experimental group was 31.833, while in the control group it was 11.028. The statistical test results showed a significance value (Sig. 2-tailed) of 0.000 < 0.05 for both groups, indicating a significant difference between the pretest and posttest scores in each group.

3.1.11 Sample t-test

Table 14. Independent Sample t-test Results

Independent Sample t-test	Pretest	Posttest
Sig. $(2-tailed)$	0.106	0.000
α	0.05	0.05
Conclusion	H_1 rejected	H_1 accepted

Based on the results of the independent sample t-test, the significance value (Sig. 2-tailed) for the pretest data was **0.106**, which is greater than α = 0.05. This indicates that there was no significant difference between the experimental group and the control group before the treatment; therefore, the initial abilities of both groups can be considered equivalent. Meanwhile, the posttest data showed a significance value of **0.000 < 0.05**, indicating a significant difference between the experimental group and the control group after the treatment was administered.

3.2 Discussion

Based on the comparative analysis between the experimental and control classes, there was a significant difference in the improvement of students' science process skills. The experimental class that implemented the Modified Free Inquiry model showed a higher improvement compared to the control class that used conventional learning. This difference can be seen from the N-Gain scores across almost all indicators of science process skills, where the experimental class consistently achieved moderate to high categories, while the control class tended to remain in the low category. These results indicate that students' active involvement in each stage of investigation within the Modified Free Inquiry model provides a more effective impact on the development of science process skills compared to teacher-centered learning. These findings are in line with the research conducted by (Suryaningsih & Mu'minah, 2022), which reported that the modified free inquiry learning approach improves students' science process skills.

Based on the implementation results of the Modified Free Inquiry model at each stage, the scores were categorized as good to very good, with an overall average of 81%. The problem orientation stage obtained a percentage of 79% in the good category, indicating that students were able to understand the problems through the Modified Free Inquiry model. The stages of problem formulation and hypothesis testing achieved very good categories, with percentages of 87% and 88%, respectively, indicating that students were actively involved in discussions to formulate questions and were engaged in practicum activities. Meanwhile, the hypothesis development and data collection stages were categorized as good, with percentages of 79% and 71%, showing that students began to be actively involved in the inquiry learning process, although some students still required guidance. At the conclusion stage, a percentage of 84% was achieved in the very good category, indicating that students were able to process experimental results and draw conclusions effectively. Overall, the high level of implementation indicates that the steps in the Modified Free Inquiry model can be applied well and support student-centered learning activities.

Based on the results of data analysis on the Science Process Skills indicators and the implementation of Modified Free Inquiry learning, a clear relationship can be seen between the execution of each learning stage and the improvement of students' SPS indicators. The implementation of the Modified Free Inquiry model obtained an overall average of 81%, categorized as very good, indicating that each stage of the learning process was carried out optimally. This finding is consistent with the N-Gain results of the experimental class, which tended to be higher than those of the control class across almost all science process skills indicators. The stages of problem orientation and problem formulation, which had high implementation percentages (79% and 87%), contributed to improvements in the observing and classifying indicators, where the experimental class achieved high N-Gain scores of 1.00 and 0.72, respectively. N-Gain scores of 1.00 in observing indicator shows that student were actively involved in simple experiments, allowing them to directly observe the phenomena. This indicates that when students actively identify problems and observe phenomena, their observation and classification skills develop more effectively. Furthermore, the stages of formulating and testing hypotheses, which were categorized as good to very good (79% and 88%), were associated with higher improvements in the interpreting, predicting, and hypothesizing indicators in the experimental class compared to the control class. In addition, the stages of collecting data and drawing conclusions, with implementation percentages of 71% and 84%, were also related to improvements in the applying concepts and communicating indicators. In the experimental class, the indicators of applying concepts and communicating showed relatively high N-Gain values (0.72 and 0.73), whereas in the control class they remained in the low category. This suggests that experimental activities, discussions, and result presentations within the Modified Free Inquiry model help students understand concepts more deeply and develop their ability to communicate findings scientifically.

This finding is consistent with the study conducted by Amanah et al. (2025) which reported that the Modified Free Inquiry model encourages students to be more active in discussions, investigations, and presenting results. Therefore, the better the implementation of the Modified Free Inquiry stages, the greater the improvement in students' science process skills. These results support the effectiveness of the Modified Free Inquiry model in promoting students' active engagement in scientific processes, in line with the science process skills theory proposed by Rustaman et al. (2005), which emphasizes observing, classifying, interpreting, and communicating results as essential components of science learning.

This study has several limitations. The implementation of this study was conducted within relatively short period, which may not fully capture long-term development of students' science process skills. In addition, the study involved only one school, which may limit generalizability of the result.

4. CONCLUSION

Based on the statistical hypothesis testing, homogeneity, and normality tests were conducted, and the data in this study were found to be normally distributed and homogeneous. Therefore, parametric tests were applied using the paired-sample *t*-test and the independent-sample *t*-test. The statistical test results indicated that the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. This result shows that there is a difference in the posttest results of students' science process skills between the control class and the experimental class. Furthermore, based on the improvement in N-Gain values for each indicator of science process skills, it can be concluded that the Modified Free Inquiry model has a significant effect on students' science process skills. In addition, this study provides valuable insights into the implementation of Modified Free Inquiry in Physics learning, particularly in static fluids.

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