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The Effect of the Modified Free Inquiry Learning Model on Students' Science Process Skills in Heat and Its Transfer Concept

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ABSTRACT

The purpose of this study was to examine the effect of the Modified Free Inquiry model on improving students' science process skills on the topic of temperature, heat, and their transfer. The research method used in this study was a quasi-experimental design with a non-equivalent control group. Participants in this study involved two groups of eleventh-grade students at a State Islamic Senior High School in Jakarta, each class consisting of 36 students. The experimental class was given learning using the Modified Free Inquiry learning model while the control group used the Discovery Learning model. The instruments used included a test instrument to measure students' science process skills and an observation sheet used to measure the implementation of learning. The results of the hypothesis test showed a p value = 0.000 (<0.05) which indicated a significant difference between the two classes with the average N-Gain values of the experimental class being 0.90 (high category) and the control class 0.58 (moderate category). The implementation of learning in the experimental class was in the good category (64%), with the problem orientation and problem planning stages reaching the highest percentage (71%). It can be concluded that the use of the Modified Free Inquiry model is effective in improving students' science process skills on the topic of temperature, heat, and their transfer.

Keywords: Science Process Skills, Modified Free Inquiry, Temperature and Heat

INTRODUCTION

One of the main concerns in physics learning in schools is science process skills which include students' abilities to interpret data, predict, ask questions, formulate hypotheses, plan experiments, use tools and materials, apply concepts, and communicate (Sholihah et al., 2020). These skills are crucial, especially in developing critical thinking and problem-solving skills, which students use to address abstract or complex physics concepts through hands-on investigations and empirical data collection. Science process skills support students in developing scientific thinking (Choudhary & Ahmed, 2022), increased problem-solving abilities (Deta et al., 2020), and enhancing scientific literacy by training students to solve everyday problems with a scientific approach (Nugraha et al., 2018).

The topic of temperature and heat is one of the topics in physics learning that presents its own challenges, because its nature tends to be visually indefinable but only through the symptoms it causes. Building an understanding related to temperature and heat will be difficult if students are only given theoretical information without involving them in exploratory activities such as scientific investigations, which of course involve science process skills. Heat and heat transfer are difficult concepts for students because of their abstract nature, which often triggers misconceptions (Sari et al., 2020). Common misconceptions in temperature and heat include: (a) the relationship between heat and internal energy (Gürçay & Gülbaş, 2016), (b) heat transfer mechanisms (Pathare & Pradhan, 2010), (c) state changes and thermal expansion (Nabilah et al., 2019), and (d) the nature of temperature as a measurable quantity rather than a subjective perception (Prince et al., 2012). Science process skills can be an important bridge for students to understand abstract physics concepts. A science process skills-based learning approach can connect familiar inquiry skills like observation and inference with more abstract scientific concepts (Bell et al., 2012), improve conceptual understanding (Inayah et al., 2020), Science process skills also allow students to apply their knowledge in practical situations, making abstract concepts more tangible (Rauf et al., 2013). Developing science process skills bridges critical thinking, links theory with reality and develops scientific literacy.

In Indonesia, science process skills remain a challenge, with various studies showing that science process skills in Indonesia are generally low across various educational contexts. Research conducted by Nurita et al. (2023) which measured the science process skills of science education students at a state university in Surabaya (N = 323) using a 50-item test, found that students' science process skills were in the inadequate category, with average scores ranging from 47.39 to 59.66 across various year groups. The lowest component was the controlling variable. Another study conducted by (Setiawan & Sugiyanto, 2020) measuring science process skills through interviews, worksheets, and questionnaires using mixed methods, the results showed low science process skills, especially in interpreting (39.4%) and communicating (18.3%) resulting in low graduation rates of science teachers in the teacher professional program. A study conducted by Irwanto et al., (2018) on undergraduate students at a state university in Yogyakarta found that students' basic and integrated science process skills were classified as moderate and low.

The low level of Science Process Skills (SPS) among students and teachers can be caused by several factors, including learning methods that are still teacher-oriented and do not involve students effectively in active learning or scientific investigation (Hutapea et al., 2021; Juniar et al., 2021) and the lack of innovative pedagogical strategies and reliance on traditional teaching methods limits the development of cognitive processes and scientific skills (Ochoa-López et al., 2022). Another factor that can also have an influence is the limited use of physics laboratories and practicals in schools which hinders the development of science process skills (Maison et al., 2019). Based on these factors, inquiry-based learning through experimental activities is an urgent need for the development of science process skills.

One learning approach that can be used to improve students' science process skills is Modified Free Inquiry. This approach develops creative thinking skills, which are an essential part of science process skills, by engaging students in a complete inquiry cycle, from problem orientation, hypothesis formulation, experimental design, to data analysis (Eristya & Aznam, 2019). This is in line with a study conducted by Nunaki et al. (2020) which shows that learning using an inquiry approach can improve students' science process skills, particularly in observation, problem formulation, hypothesis formulation, and communication. The advantage of this approach is its emphasis on independent exploration and experimental design, which can provide experiences with deeper reflection on how scientific processes are carried out.

This study aims to implement the Modified Free Inquiry approach as a strategic solution in improving students' science process skills in temperature and heat materials through active involvement in the scientific inquiry process.

METHOD

This study used a quasi-experimental method with a non-equivalent control group design. The experimental class was taught with Modified Free Inquiry (MFI), while the control class implemented the discovery learning model. Before the treatment was administered, both classes were given a pre-test to determine their initial abilities, and at the end, a post-test was given to determine their final abilities after the treatment. This design allows us to determine the effect of the Modified Free Inquiry learning model on students' science process skills.

Participants consisted of 72 eleventh-grade students (ages 16-17) from two intact classes at a State Islamic Senior High School in Jakarta and selected through convenience sampling in conjunction with the physics instructor, contingent upon school accessibility and class availability. One class served as the experimental group (n = 36) and the other as the control group (n = 36). All participants were enrolled in the grade XI physics course and completed both the pretest and posttest of science process skills. The research instrument used a science process skills test instrument compiled using nine of the 10 indicators of the Science Process Skills (KPS) proposed by Suja (2020), including: (1) classification, (2) interpretation, (3) prediction, (4) asking questions, (5) hypothesizing, (6) planning experiments, (7) using tools and materials, (8) applying concepts, and (9) communicating. The remaining indicator, observation, was not evaluated due to the use of a written test format, which is insufficient to provide a valid assessment of students' direct observation abilities. In addition, observation sheets are also used to determine the implementation of learning. Data analysis techniques implemented include:

1. Normality test using Shapiro-Wilk with the help of IBM SPSS Statistics 25 software to find out whether the pretest and posttest data from the experimental class and control class are normally distributed.
2. Homogeneity test using Levene's Test at a significance level of 5% to ensure equality of variance between groups.
3. N-Gain Calculation, Used to measure the improvement in students' science process skills after treatment. The equation used is

$$g = \frac{Posttest\ Score - Pretest\ Score}{maximum\ score - pretest\ score} \ldots (1)$$

The classification of value increase based on N-gain is given in table 1:

Table 1. Categorization of N-gain Values.

Mark	Category
g ≥ 0.70	High
0.30 ≤ g < 0.70	Moderate
g < 0.30	Low

4. Hypothesis testing is carried out based on the results of the normality test. For data that is not normally distributed, hypothesis testing uses a non-parametric test, namely the Mann–Whitney U at a significance level of 5%.
5. Learning Implementation Analysis, an analysis of the learning implementation was conducted in the experimental class which was used to determine the percentage of implementation of each stage in the Modified Free Inquiry model as data analysis material to link the implementation of each stage with the achievement of students' science process skills (KPS). Implementation was carried out using the equation:

$$Percentage = \frac{Score\ Obtained}{Maximum\ Score} \text{x } 100\% \ \ldots .\ (2)$$

The implementation category refers to the following criteria:

Table 2. Categorization of Implementation.

Percentage	Category
85–100%	Very good
69–84%	Good
53–68%	Adequate
37–52%	Poor
<37%	Very Poor

RESULTS AND DISCUSSION

Results

Students' Science Process Skills Improvement

The improvement in students' science process skills in both groups was calculated based on the average N-gain score. Details of the N-gain in both groups are presented in Table 3.

Table 3. Overall N-Gain Results

Class	N-Gain	Information
Control	0.58	Moderate
Experiment	0.90	High

Based on the research results, it was found that in the experimental class, students' science process skills increased with an N-Gain value of 0.90 (high category), while in the control class the increase was 0.58 (moderate category). Based on these results, it can be concluded that students' science process skills in the experimental class experienced a higher increase than the group of students in the control class.

Table 4 presents the N-Gain values of students' science process skills for each indicator for the control class and the experimental class along with their categories.

Science Process Skills Indicators	Control Class	Note	Experimental Class	Note
Classification	1.00	High	1.00	High
Interpretation	0.52	Moderate	0.91	High
Prediction	0.59	Moderate	0.88	High
Ask a Question	0.61	Moderate	0.86	High
Hypothesize	0.57	Moderate	0.89	High
Planning an Experiment	0.66	Moderate	0.85	High
Using Tools and Materials	0.56	Moderate	0.95	High
Applying the Concept	0.29	Low	0.88	High
Communicate	0.63	Moderate	1.00	High

The classification indicators in both classes achieved an N-Gain of 1.00 (high category). A striking difference was seen in the concept application indicator, with the experimental class achieving 0.88 and the control class achieving 0.29. All indicators in the experimental class had an N-Gain above 0.85 (high category), while the control class generally achieved 0.52–0.64, indicating a more significant increase in science process skills in the experimental class.

Prerequisite Test Results

The normality test was conducted using SPSS Staristics 25 software using the Shapiro-Wilk test method. The results of the normality test in this study are presented in the following table.

Table 5 Normality Test Results

Shapiro-Wilk	Experimental Class Pretest	Control Class Pretest	Experimental Class Posttest	Control Class Posttest
Df	36	36	36	36
α	0.05	0.05	0.05	0.05
Significance	0.011	0.067	0.000	0.004
Decision	Not Normally Distributed	Normally Distributed	Not Normally Distributed	Not Normally Distributed

The results of the homogeneity test of the pretest and posttest values in this study were obtained using IBM SPSS Statistics 25 software. Meanwhile, the results of the homogeneity test are shown in the following table.

Table 6. Results of Homogeneity Test

Levene Statistics	Pretest	Posttest
Significance	0.725	0.000
α	0.05	0.05
Decision	Homogeneous	Not Homogeneous

Based on the normality test and homogeneity test, it can be concluded that the pretest and posttest data in both classes do not all have normally distributed, homogeneous data. Therefore, the hypothesis test uses non-parametric statistics, the Mann Whitney U test, with the SPSS Statistics software application. The results of the hypothesis test are presented in table 7.

Table 7 Hypothesis Test Results

	Pretest (Mann-Whitney)	**Posttest (Mann-Whitney)**
Sig. (2-tailed)	0.000	0.000
α	0.05	0.05
Decision	H_0 rejected	H_0 rejected

The results of the Mann Whitney non-parametric statistical test on the pretest data show a significance value (Sig.2 tailed) of 0.000 which is smaller than α = 0.05, so H 0 is rejected. then there is an influence of the use of the *Modified Free Inquiry learning model* on science process skills.

Results of the Analysis of the Implementation of Experimental Class Learning

The implementation of the Modified Free Inquiry model learning process during three meetings is presented in the following table.

Table 8. Percentage of Implementation of Modified Free Inquiry

No	**Learning Stages**	**Meeting 1**	**Meeting 2**	**Meeting 3**	**Average Percentage**	**Category**	**Overall average**
1	Problem Orientation	86%	72%	56%	71%	Good	64%
2	Formulating the Problem	86%	72%	56%	71%	Good	
3	Proposing a Hypothesis	67%	53%	33%	51%	Adequate	
4	Planning an Experiment	83%	58%	61%	67%	Good	
5	Conducting an Experiment	78%	60%	65%	68%	Good	
6	Analyzing Data	73%	62%	59%	65%	Good	
7	Communicating	47%	61%	53%	54%	Adequate	
8	Conclude	72%	58%	64%	65%	Good	

Overall, the learning implementation using the Modified Free Inquiry model reached 64%. The problem orientation and problem formulation stages achieved the highest percentages, each at 71%. Meanwhile, the stages with the lowest implementation percentages were proposing a hypothesis (51%) and communicating (54%).

Discussion

The significant difference in science process skills between the experimental and control groups provides strong evidence for the effectiveness of the Modified Free Inquiry approach in developing students' investigative competencies in abstract physics concepts such as heat and its transfer. The increase in the experimental group was in the high category compared to the moderate increase in the control group. This shows that the application of the Modified Free Inquiry model in learning the topic of heat and its transfer has a positive impact on students' science process skills. This finding is in line with research conducted by Marta et al. (2018) which shows that the use of the Modified Free Inquiry method can improve students' science process skills. The Modified Free Inquiry learning model has shown potential in improving students' science process skills because this model emphasizes independent exploration, designing, and conducting experiments, which are important for developing creative thinking skills in science learning (Eristya & Aznam, 2019) .

The indicator *of applying concepts* also showed a significant increase in the experimental class with an N-Gain of 0.88, significantly higher than the control class (0.29). This indicates that the Modified Free Inquiry model is very effective in building students' conceptual understanding. This is in line with Gkagkas & Hatzikraniotis (2024) who stated that this model focuses on improving students' cognitive abilities for evidence-based investigations, promoting holistic development and academic success. In addition, other indicators such as using tools and materials (0.95), hypothesizing (0.89), and prediction (0.88) also reached the high category. This indicates that the Modified Free Inquiry learning model is effective in training students in the skills carried out in scientific processes. This is in line with Tornee et al. (2017) who stated that inquiry-based learning emphasizes independent learning and improving students' abilities in scientific literacy.

The implementation of research at each stage of modified free inquiry is in the good and sufficient category, the problem orientation and problem formulation stages obtained the highest average percentage (71%, good category) this is in line with the increase in classification indicators in the high experimental class (N-gain, 1.00). In addition, the stages of conducting experiments (68%) and planning experiments (67%) also showed implementation in the good category so that it can explain the high increase in the indicators of using tools and materials (0.95) and hypothesizing (0.89). Overall, the implementation of modified free inquiry learning reached the good category (64%) so that it shows a contribution to the increase in KPS on each indicator in the experimental class.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the use of the Modified Free Inquiry learning model significantly improves students' science process skills on temperature and heat material based on the results of hypothesis testing using the non-parametric Mann–Whitney U test at a significance level of 5%. The increase in KPS in the experimental class is in the high category with an average N-Gain of 0.90, superior to the increase in the control class which is in the medium category with an average N-Gain value of 0.58. Almost all KPS indicators in the experimental class experienced a higher increase than the control class except for the classification indicator where both received the same N-Gain (1.00). The highest increase was in the classification and communication indicators (N-Gain 1.00).

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