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Learning Physics with a Free Discovery Model to Improve Critical Thinking Skills of High School Students

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Abstract

Critical thinking abilities are extremely important in 21st-century learning. The goal of this study was to determine the effectiveness of the free discovery learning paradigm in developing high school students' critical thinking skills. The research approach was a one-group pre-test and post-test design with repeated pre-experimental research without a control group. Before learning, students were given a pre-test, and after learning, they were given a post-test with the same material. The sample used in the study comprised 72 MAN Sidoarjo students divided into two classes, namely class XI MIPA 6 and XI MIPA 7. Critical thinking skills tests and student response questionnaires were utilized as instruments in this study. Paired t-tests, n-gain calculations, independent t-tests, and student response questionnaire analyses were among the data analysis approaches used in this study. With an average n-gain score included in the moderate criteria in the two experimental classrooms, the value of students' critical thinking skills increased.There was no difference in the average n-gain value between the two experimental classes. The average percentage of student responses to learning the free discovery model was in the excellent category of 81.56% and 80.78%. So, it can be concluded that the free discovery learning model effectively improves the critical thinking skills of high school students. This study implies that physics learning with a free discovery model can be helpful for teachers in improving the critical thinking skills of high school students.

Keywords: Physics, Free Discovery Learning, critical thinking skills

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INTRODUCTION

The balance between science and technology has marked the development of the 21st century (IPTEK). Humans are believed to be capable of critical thinking.. Thus, the existence of competencies can form creative, innovative, collaborative, competitive, and comparative human resources. Learning 21st century Education demands a higher level of thinking ability. The expected learning is innovative, creative, collaborative, and student-centered (Erlina Yusliani, Hanana Laila Burhan & Program, 2019). Learning in the 21st century prioritizes cognitive abilities and students' skills (Winata et al., 2019). Education in the 21st century requires a variety of abilities, including information, attitudes, and skills.. The educational goals of the 21st century can be achieved if students have critical thinking skills, have broad insights, can work together and communicate well, and can create and renew work.

According to Najib and Jatmiko (2022), Humans have the ability to think critically, but it must be developed in order to reach its full potential. Critical thinking skills are very important to be able to compete in today's era of globalization. Critical thinking skills are important in the 21st century because they help us to be more skeptical of events. However, it is processed first so that it becomes valid and real. However, in reality, the applied physics

learning model still emphasizes memorizing formulas and materials alone, so critical thinking skills have not been fully honed, and the demands of the 21st century have not been resolved.

Erlina Yusliani (2019) said that one of the efforts to respond to the demands of the 21st century is for the government to provide solutions by designing the quality of education in Indonesia and evaluating and developing the curriculum by creating a new curriculum that demands students to be more active in the learning process, curriculum development is done to improve the quality of education. The 2013 Curriculum is a new curriculum that encourages students to participate more actively in their learning. The 2013 curriculum is a curriculum that focuses on forming competencies, skills, and attitudes that students can demonstrate as a form of understanding of the concepts they learn by combining knowledge and skills. The goal of the 2013 curriculum is to strike a balance between the knowledge and skills of learners. Several educational concepts are contained in the 2013 curriculum, including 21st-century skills, scientific approaches, and authentic assessment. The learning process and models strongly influence the three educational concepts and teaching materials educators use in learning activities. Learning models that are seen as helpful and facilitated to make it easier for students to master physics concepts and practice developing critical thinking skills include the free discovery learning model. The discovery learning model, also known as discovery-based learning, is a teaching method that allows students to discover concepts and theories of knowledge for themselves by making observations, classifying, and finding them. The discovery learning model is divided into two: guided discovery and free discovery. Guided discovery is a problem-solving-based learning model that aims at self-development and sustainability, where students are taught to identify goals and implement them with little guidance or assistance from teachers (Onikarini et al., 2019).

In learning with a free discovery model, two-way learning occurs, meaning learning is centered on the teacher and student-centered learning. Students independently find learning goals and learning experiences that are cool. The teacher only provides stimulus in the form of problems and learning situations. So, what is considered more suitable for improving critical thinking skills is the free discovery model. The free discovery learning model allows students to develop critical thinking skills and become more self-sufficient in problem-solving. And the results obtained by open-ended are not just racing to one answer. According to Syamsu (2020) learning with the Free Discovery model is more effective than conventional learning which is only one way without involving students in the learning process, based on the results of questions and answers with the physics teacher at MAN Sidoarjo, learning in class tends to be passive, the learning model used is monotonous, students less involved in the learning process, learning is only centered on the teacher with the lecture method, this is the main cause of students having difficulty improving critical thinking skills. It can be integrated through learning tools using the free discovery paradigm to increase students' critical thinking skills, according to some of the arguments above. The goal to be achieved is that students can find concepts that match the material given, and students' critical thinking skills can be honed.

This research is a follow-up study (Fahmi et al., 2019) regarding learning with the Free Discovery model to train students' critical thinking skills.The overall goal of this research is to describe the efectiveness of using a free discovery approach to teach physics to students in order to develop their critical thinking skills. Indicators of critical thinking skills are; Interpretation, analysis, evaluation, inference, explanation, self regulation (Arif et al., 2017).

METHOD

The method used in this study was repeated pre-experiments without control because, in this study, there were still other variables that influenced the response variables. The researcher employed a one-group pre-test and post-test design in this study. (Nuryanti, 2019). The study design is illustrated in Table 1

Table 1. One Group Pre-test and Post-test Design Research

Class	Pre-test	Treatment	Post-test
XI MIPA 6	O_1	X	O_2
XI MIPA 7	O_1	X	O_2

Description :

O_1 : Pre-test before treatment
X : The application treatment of the Free Discovery learning model
O_2 : Posttest after treatment

This research was conducted at MAN Sidoarjo with research subjects consisting of two classes, XI MIPA 6 and XI MIPA 7, given a pre-test before being given treatment and then given treatment using a free discovery learning model on doppler effect material. After the treatment, the same material was used for a post-test or final testThe impact of the free exploration learning approach on students' critical thinking skills was assessed using the results of the post-test or final test. The sample for this study was divided into two classes: XI MIPA 6 and XI MIPA 7, each of which amounted to 36 students. The study was conducted face-to-face (offline). During the learning process, students are also trained in problem-solving skills contained in the learner worksheet. This study used a critical thinking skills instrument with six indicators: analysis, evaluation, inference, explanation, and self-regulation (Arif et al., 2017). The N-gain formula is used in this study to determine the criteria for increasing the value of students' critical thinking skills.

$$N - gain(g) = \frac{Score_{post} - Score_{pre}}{Score_{max} - Score_{pre}},$$

Description:

g = *N-Gain*
Score $_{post}$ = post-test score
Score $_{pre}$ = pre-test score

The results of the N-gain computation are then classified in Table 2

Table 2 N-Gain Classification

Score	N-Gain Class
0,7 < N-gain	High
0,3 ≤ N-gain ≤ 0,7	Moderate
N-gain < 0,3	Low

This study was effective in enhancing critical thinking abilities if there was a statistically significant increase in critical thinking skill scores at 5% alpha, the average n-gain was at least in the moderate category, the average n-gain was not different in the two experimental classes after receiving treatment, and there were positive student responses to learning with a free discovery model

RESULTS AND DISCUSSION

In general, the research results described in this section are about the average value of pre-test and post-test, testing assumptions, and hypothesis testing. One physics subject teacher at MAN Sidoarjo and two expert lecturers from the Physics department, Faculty of Mathematics, State University of Surabaya validated instruments in the form of syllabus, lesson plans, learner worksheets, pre-test and post-test questions, and student response questionnaires before conducting research at MAN Sidoarjo.The results of the validity of learning tools using the free discovery learning model as described in Table 3

Table 3. Results of the Validity of learning instrument

No	Research Instrument	Average grades	Criteria
1	Syllabus	3,6	Very valid
2	Lesson Plans	3,65	Very valid
3	Learner worksheets	3,75	Very valid
4	Pre-test and post-test questions	3,5	Valid
5	Student response questionnaires	3,5	Valid

Table 3 demonstrates that the average value of the outcomes of the validity of learning instruments, which include syllabus, lesson plans, and learner worksheets are a very valid criterion. In addition, pre-test and post-test questions are in the valid category. So that it can be concluded that learning instruments using the free discovery model are worthy of use for research at MAN Sidoarjo.

Description of Research Variables

This study examined the influence of free-discovery learning models on the critical thinking skills of high school students. Before the learning process using the free discovery model, students were given a pre-test first to find out their initial ability. Then, after the learning process has been carried out using the free discovery model, and after learning using the free discovery model, a post-test with the same material would be given to students to measure their final ability. Before conducting influence testing, an analysis of the description of the research variables was carried out. Variables' descriptions The study looked at the mean value, standard deviation, as well as the minimum and maximum values. The result of the variable description is described in Table 4 as follows:

Table 4 Student Critical Thinking Skills Value Data Description Results

Descriptive	XI MIPA 6		XI MIPA 7	
	Pretest	Posttest	Pretest	Posttest
Minimum	54,00	58,00	56,00	60,00
Maximum	87,00	90,00	86,00	88,00
Mean	71,8611	74,9444	71,9722	74,8056
Standard Deviasi	8,81931	8,61873	7,33479	7,22622

In both classes XI MIPA 6 and XI MIPA 7, Table 4 demonstrates that the average pre-test score before learning with the free discovery model is lower than the average post-test score after learning with the free discovery model.

Data Normality Test

The analytical precursor test was carried out first, utilizing a data normality test on six legitimate question items, before completing a statistical analysis test. This study's normality test was used to determine whether the data were distributed normally. The test used was with Saphiro Wiilks (Quraysh, 2020). The test requirements specify that the data follows the normal distribution if the significance value is greater than the level of significant alpha, which is set at 5% or 0.05. The findings of the data normality test are as follows:

Table 5 Data Normality Test Results

Test	XI MIPA 6			XI MIPA 7		
	Statistic	Sig.	Description	Statistic	Sig.	Description
Pre-test	0,965	0,302	Normal	0,958	0,182	Normal
Post-test	0,972	0,481	Normal	0,961	,236	Normal

Table 5 demonstrates that the final significance value is greater (>) than a significant alpha (5 percent or 0.05). Therefore, in order to satisfy the assumption of normality, it can be said that the post-test and pre-test data in both groups and classes follow the normal distribution. Because the data were normally distributed, the analysis used in this study used parametric analysis.

Homogeneity Test Data

This study used the homogeneity test to determine whether the data had a homogeneous variety. The test used was Levene's test. The homogeneity test was used in parametric tests to test the differences between two groups of subjects. In addition, the homogeneity test was needed for the assumptions of the independent t-test (Ramadhani, 2017). The following test criteria state that if the significance value is greater than the level of significant alpha is 5% or 0.05, it is stated that both groups have a homogeneous variety. The findings of the data homogeneity test are as follows:

Table 6 Data Homogeneity Test Results

Test	F Statistic	Sig.	Description
Pre-test	1,522	0,221	Homogen
Post-test	0,803	0,373	Homogen

Based on Table 6, it can be seen that the resulting significance value > significant alpha (5% or 0.05). Therefore, it can be concluded that the variance of class XI MIPA 6 is the same as that of XI MIPA 7 or that the N-gain value of both classes is homogeneous.

Paired t-test

To see the improvement of students' critical thinking skills in both classes, it was carried out using a paired t-test analysis. The test criteria state that if the significance value < the significance level (alpha = 5% or 0.05), it can be stated that the free discovery learning model influences students' critical thinking skills. The following is a description of the paired t-test results in Table 7:

Table 7 Result of Paired t-test

Group	Test	Average	Statistics	*Sig.*	Description
XI MIPA 6	Pre-test Post-test	71,8611 74,9444	-9,499	0,000	Significant
XI MIPA 7	Pre-test Post-test	71,9722 74,8056	-6,506	0,000	Significant

Table 7 shows that the results of statistical test analysis using paired t-tests for groups XI MIPA 6 and XI MIPA 7 yielded significance values alpha (5 percent or 0.05). H0 was then refused, whereas H1 was accepted. That is, there is a considerable difference in the value of students' critical thinking skills before and after being treated with the free exploration learning paradigm. Or in other words, there is a significant influence when the free discovery learning model is applied to students' critical thinking skills. Because the t value is negative, it can be concluded that the average score during the post-test is higher than during the pre-test. It shows that the application of the free discovery learning model has been shown to be able to improve students' critical thinking skills significantly.

Judging from the statistical scores between the two groups/classes, it can be concluded that the influence of the free discovery learning model on the critical thinking skills of class XI MIPA 6 students was greater than that of class XI MIPA 7. The statistical t value indicates that class XI MIPA 6 is higher than class XI MIPA 7.

Independent t-test

Then, using an independent t-test analysis test, to find out how the two classes differ in terms of developing students' critical thinking abilities XI MIPA 6 and XI MIPA 7. The test criteria state that if the level of significance (alpha = 5% or 0.05), then there is a difference in the influence of the free discovery learning model on critical thinking skills of high school students in classes XI MIPA 6 and XI MIPA 7, or the application of the free discovery learning model has a different influence between classes XI MIPA 6 and XI MIPA 7. The following are the findings of the analytical test:

Table 8 Independent t-Test Results

Test	Mean Difference	Statistics	*Sig.*	Description
Pretest	-0,11111	-0,058	0,954	Insignificant
Posttest	0,13889	0,074	0,941	Insignificant

Table 8 shows that the results of statistical test analysis with an independent t-test during pre-test and post-test resulted in a significant value of > alpha during pre-test and post-test (5 percent or 0.05). H0 was accepted, while H1 was turned down. It reveals that both groups/classes XI MIPA 6 and XI MIPA 7 had critical thinking skills values that were similar before and after the free discovery learning methodology was implemented. In addition, to establish the category of improving the value of important abilities, an N-gain analysis of the pre-test and post-test values is performed.

N-Gain Analysis Results

The results of the N-gain calculation are presented in Table 9 as follows:

Table 9 Hasil N-Gain

Class	Score (g)	N-Gain Category
XI MIPA 6	0,6268	moderate
XI MIPA 7	0,6130	moderate

The N-Gain values for classes XI MIPA 6 and XI MIPA 7 are 0.6268 and 0.6130, respectively, as shown in Table 9. The value is below the 0.3 N-gain 0.7 range. As a result, it falls into the moderate group. It shows how critical thinking skills improved before and after students were given a free exploration learning model in the moderate category.

Percentage of Student Responses

Table 10 Percentage of Student Responses to the free discovery learning model

Class	Average response (%)	Criteria
XI MIPA 6	**81,56**	Excellent
XI MIPA 7	**80,78**	

According to Table 10, the average response in each category class is very goodBased on the responses to the questionnaire provided to students following their use of the free discovery model of learning,most students feel interested in the learning provided.

Using Table 3, a study of the description of the research variables was carried out. Descriptions of variables In order to conduct the study, mean values, standard deviations, minimum and maximum values, and consecutive pre-test average values of 71.86 and 71.97 for both classes were used, followed by post-test average consecutive values of 74.94 and 74.80. It indicates that the average pre-test scores in both classes XI MIPA 6 and XI MIPA 7 were lower before learning with the free discovery model than the average post-test score after learning with the free discovery model. Discovery learning is a learning model where students are required to independently find a concept in learning, investigate and solve a problem so that the results of learning will be easier for students to remember and become

knowledge that is not easily forgotten. Learning with the discovery learning model is divided into two: guided discovery and free discovery. Where learning with the free discovery model, the teacher will not play many roles in learning, only providing stimulus and learning situations. Hence, the students are active in the learning process, such as looking for problem formulations and answers to the formulation of the problem (problem-solving). According to Putri et al. (2017), Stimulation (stimulus/stimulation), problem statement (statement/issue identification), data collection, data processing, verification (proof), and generalization are the syntax of the free discovery learning model . The Discovery Learning model has an impact on psychomotor or student abilities, since students can think critically while learning, with the teacher giving opportunities for students to participate actively in the learning process. Teachers also give children opportunity to solve problems by helping them build analytical abilities and learn how to process information. (Nugrahaeni et al., 2017). The learning process began with prayer and continued with student attendance checks.

The students next watched a movie about the Doppler effect, which served as their initial perception or stimulus. After being given an initial perception or stimulus, the student was expected to be able to connect with daily life about things related to the Doppler effect. The students were then divided into groups and handed learner workbooks with problem-solving tasks to help them improve their critical thinking skills. In addition, a paired t-test was used in Table 7 to see if there were any significant differences when using the free discovery model. The findings of statistical test analysis with paired t-tests of groups XI MIPA 6 and XI MIPA 7 resulted in a significance value of alpha in Table 7. (5 percent or 0.05). As a result, it's possible to conclude that there are considerable changes in the value of students' critical thinking skills before and after they've been exposed to the free exploration learning paradigm. In other words, when the free exploration learning approach is applied to students' critical thinking skills, it has a big impact. Because the t value was negative, it's safe to assume that the average post-test score was higher than the pre-test score. It demonstrates that using the free exploration learning methodology has been shown to greatly increase students' critical thinking skills. It is based on scientific evidence. (Nugrahaeni et al., 2017), According to this study, learning with a free discovery approach can help pupils develop their critical thinking skills.

Table 8 shows the results of an independent t-test to identify the difference in critical thinking skills improvement between classes XI MIPA 6 and XI MIPA 7. Table 8 shows that the pre-test and post-test findings of statistical test analysis with independent t-tests resulted in a significant value of > alpha (5 percent or 0.05). Furthermore, it demonstrates that both groups/classes XI MIPA 6 and XI MIPA 7 had critical thinking skills values that tended to be the same before and after the free exploration learning paradigm was implemented. As a result, using the free discovery learning paradigm to increase critical thinking skills in both classes XI MIPA 6 and XI MIPA 7 may be concluded.

The N-gain value of the two experimental classes was calculated using Table 9, and the N-gain value of the two experimental classes was obtained in the medium category. Because the N-gain values in the two experimental courses were not different, It may be said that using the free discovery model to learn helps students develop their critical thinking abilities.

Table 10 shows that the average response in each category class was excellent, with percentages of 81.56 percent and 80.78 percent, respectively. When presented with a free exploration learning paradigm, the majority of pupils are enticed. The free discovery model makes it simpler for students to learn new things, comprehend concepts, link concepts to real-life situations, and solve problems so they may draw conclusions based on the material they have been taught that are scientifically and factually accurate. The free discovery learning model was effective in increasing the critical thinking skills of class XI MIPA 6 and MIPA 7 MAN Sidoarjo. It is corroborated by previous research by (Putri et al. 2017);(Fitriana 2019);(and Nugrahaeni et al., 2017). It can be seen from the results of statistical test analysis with paired t-tests in classes XI MIPA 6 and XI MIPA 7, which produced a significance

value of < alpha (5% or 0.05), that there was a significant increase in the value of critical thinking skills between before being given learning with a free discovery model and afterward. The results of statistical test analysis with independent t-tests during pre-test or post-test produced a significance value of > alpha (5% or 0.05), which means that when before and after being given the free discovery learning model, the condition of the two classes tended to be the same. The average N-gain score in the two experimental classes was in the medium range; The average student response rate to learning the free discovery model was in the very good range, and there was no difference in the average N-gain between the two experimental classes. so it can be concluded that using the free discovery learning model to improve critical thinking skills in students is effective.

CONCLUSION

Based on the findings of the research, it can be concluded that the free discovery learning model at MAN Sidoarjo effectively develops students' critical thinking skills. It may be seen from the statistically significant rise in the value of critical thinking skills at a high level of 5% alpha ,there is no difference in critical thinking skills between the two classes, and the average percentage of student responses to free discovery model learning is in the excellent category.

RECOMMENDATION

The advice given by researchers suggests that physics teachers should be more creative in providing learning; preferably, the learning model given is not boring, not just one direction centered on the teacher, so that students can explore their knowledge that can improve their critical thinking skills.

ACKNOWLEDGMENT

The advice given by researchers suggests that physics teachers should be more creative in providing learning; preferably, the learning model given is not boring, not just one direction centered on the teacher, so that students can explore their knowledge that can improve their critical thinking skills.

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