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Development of PhET-Aid-Based Inquiry Learning Devices to Improve Student Critical Thinking Skills

N. R. Kapelle [1]; B. Jatmiko; Munasir; I. H. Wenno [2]

[1] Postgraduate of Surabaya State University, Surabaya, Indonesia

[2] Pattimura University, Maluku, Indonesia

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Abstract

This study aims to produce a valid, practical and effective PhET-assisted inquiry learning model to improve students' critical thinking skills. Development of learning tools using the 4D model. Learning tools developed are syllabus, lesson plans, student worksheets and student textbooks. The feasibility level of the device is known through validation conducted by two lecturers. To determine the achievement of student learning outcomes used test questions using the pretest-posttest design method. The learning device trial was carried out on 60 students of class IX SMP Negeri 9 Ambon consisting of two groups namely Class IX-10 and Class IX-11. The results of the validity of the learning tools validated by the lecturers obtained the average percentage results namely syllabus 98.95%, lesson plans 99.23%, student worksheets 99.24%, Student Textbooks 98.72% and critical thinking skills test questions 96.47 %. From the results of the research that has been carried out it can be concluded that: 1) The validity of the learning tools that have been developed as a whole are categorized as good and suitable for use in learning; 2) The practicality of the developed learning tools includes the implementation of lesson plans categorized as good and can run well based on student responses; 3) the effectiveness of the learning device is shown by an increase in students' critical thinking skills based on the results of the t-test and n-gain scores.

Keywords: PhET Simulation; Learning Tools; Inquiry Model; 4D Model

1. Introduction

The 21st century has only been running for a decade, but in the world of education the impact has been felt by the changes and shifts that are fundamental at the philosophical level and the direction of its goals. It's no exaggeration to say that the progress of science is based on the birth of computer science and technology. In the context of the use of information and communication technology in the world of education, it has been proven to be increasingly narrow and the fusion of space and time factors that have been a critical determinant of the success of science (BSNP, 2010).

Educational outcomes expected in the 21st century education include patterns of competence and intelligence. Education is not only preparing the future, but also how to create the future. Education must foster the development of critical individuals with a very high level of creativity and high thinking skills. The teacher must also be able to provide skills that can be used at work. Teachers will fail if they use a learning process that does not affect long life education (Rusman, 2012).

Ennis 1985; Panich 2012, as written in Sinprakob & Songkram (2015) critical thinking is an important skill for learning in the 21st century. Instructors are needed to find ways to design learning for students, both during certain ages to practice critical thinking that occurs at any time of interaction between instructors and students. Critical thinking will come from students' perceptions or renditions and depends on individual understanding of various aspects as well as age and experience. In addition, critical thinking must occur unconsciously as a student's daily life until it becomes a habit known as critical thinking skills.

Florea & Hurjui (2014) state that critical thinking is a basic skill that develops interesting early learning exercises and activities, teaching and learning methods vary and depends on the actual educational situation (static context) and the stage of development of critical thinking (dynamic context).

Adam (2010) states that the application of inquiry models can improve the mastery of concepts and critical thinking skills. Because the inquiry learning model is a learning model that emphasizes the process of thinking critically and analyzing to find and find answers for themselves on a problem (Sanjaya, 2009).

The inquiry learning model has advantages that enable students to use all intellectual processes to find scientific concepts and principles and provide many advantages that are helping students carry out investigations, enhance understanding of concepts, develop creativity, make student-centered learning processes that give students opportunities to understand and collect information (Slamento, 2013).

Well-designed computer simulations, used as part of inquiry-based teaching models, can significantly help students develop scientific understanding,thinking skills, scientific argumentation, idea development, conceptual evolution and active involvement (Fernandes, 2019). Provision of subject matter by utilizing high technology such as the use of satellites, television, radio, or telephone, teleconferencing or distance learning programs such as the existence of computer-assisted instruction, makes learning interesting, because displays from the screen can be made with a variety of interesting variations (Munir, 2012).

Simulation media is basically one of the learning media that aims to provide a more concrete learning experience through the creation of imitations of experiences that approach the real atmosphere with visual appearance. The simulation that will be used in this research is to discuss dynamic electrical material in the PhET titled Circuit DC Only.

2. Methodology

This research is a research development using the 4D development model according to Thiagarajan and Sammel (1974) which consists of four stages, namely, define, design, develop, and disseminate. However, the deployment stage was not carried out because the trials in this study were only limited trials.The subjects in this study were physics learning tools with PhET-assisted inquiry models to improve students' critical thinking skills on the subject of dynamic electricity, while the subjects of this research were class IX students of SMP Negeri 9 Ambon consisting of two classes, namely classes IX-10 and IX - 11.The trial design was implemented using the One-Group Pretest-Posttest Design developed by

Campbell and Stanley (Arikunto, 2010). The learning device was validated by two lecturers as validators. The trial was conducted on students of class IX-10 and IX-11 of SMP Negeri 9 Ambon, to find out the application of the influence of the application of the developed learning tools. The instruments used to collect research data were validation sheets, observation sheets, learning achievement test sheets, and student response questionnaires.

3. Findings and Discussion

3.1 Fidings

Physics learning tools using PhET-assisted inquiry models to improve students' critical thinking skills on dynamic electric material that are developed are suitable for use in learning. This is based on the results of syllabus validation, lesson plans (RPP), student textbooks (BAS), student activity sheets (LKS), and test instrument as in Table 1.

Tabel 1. Validity and Reliability of Learning Devices

Learning Tool	Validity	Category	Reliability (%)	Category
Syllabus	3.65	Very valid	98.85	Reliability
RPP	3.64	Very valid	99.24	Reliability
LKS	3.47	Valid	99.20	Reliability
BAS	3.55	Valid	98.72	Reliability
Test instrument	3.54	Valid	96.47	Reliability

Table 1 shows that the validity and reliability of RPP are categorized as very valid and reliable, LKS, BAS, and test instruments are all valid and reliable. This means that learning tools and test instruments are feasible and can be used in this study.

Analysis of the practicality of learning tools to describe the process of the ongoing implementation of learning activities using a PhET-assisted inquiry model including the implementation of learning plans (RPP). To find out the average results of observing the implementation of the RPP can be seen in Figure 1.

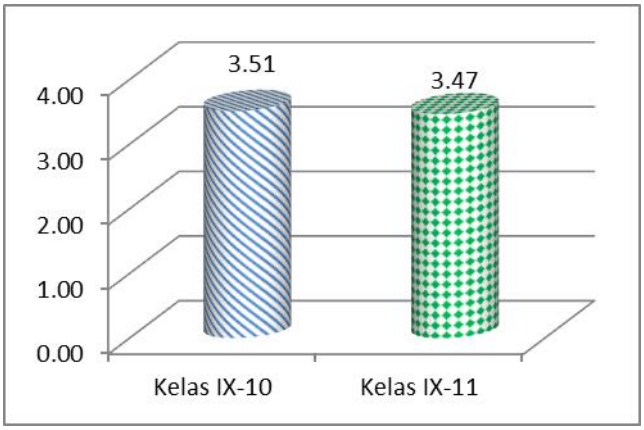

Figure 1. Graph of Average RPP Implementation

Based on the results in Figure 1 shows that in general the implementation of the RPP in the second obtained the average results of observations of 3.51 and 3.47 categorized as good, with a range of observational assessment scores from 1 to 4.

The effectiveness of the learning tools in this study were reviewed from the results of tests of critical thinking skills, student activities and student responses during the learning process taking place using the PhET-assisted inquiry model. Based on the scores of the students' critical thinking skills test results before learning is done using the PhET-assisted inquiry model and after learning in both groups: class IX-10 and IX-11, the mean scores of pre-test and post-test are presented as presented in Table 2.

Table 2. Average Pre-Test and Post-Test Scores of Two Groups of Students

Average Student Score	Group	
	Class IX-10 : N=30	Class IX-11 : N=30
Pre-test	20.75	18.42
Post-test	74.25	76.17

Table 2 shows that the students' critical thinking skills test scores before learning by using a PhET-assisted inquiry model in both groups of students is very low, which is less than 20 in the range of scores 0-100. Meanwhile, after learning, the scores in both groups of students become high, namely 74.25 for class IX-10 and 76.17 for class IX-11.

Improving the results of students' critical thinking skills can be done by inferential statistical analysis through the analysis of N-Gain scores. To find out the average N-Gain results in both groups can be seen in Table 3.

Table 3. Average N-Gain Scores in Two Groups of Students

Group	**N-gain**	**Category**
Kelas IX-10	0.67	Medium
Kelas IX-11	0.71	High

Based on Table 4.14 obtained information that the results of the N-gain pre-test and post-test critical thinking skills of students in class IX-10 obtain an average score of N-gain of 0.67 in the medium category and for the results of N-gain in the class IX-11 which is 0.71 with the moderate category. To find out the number of students who get N-Gain grades with high, medium, and low categories in both classes is presented in Figure 2.

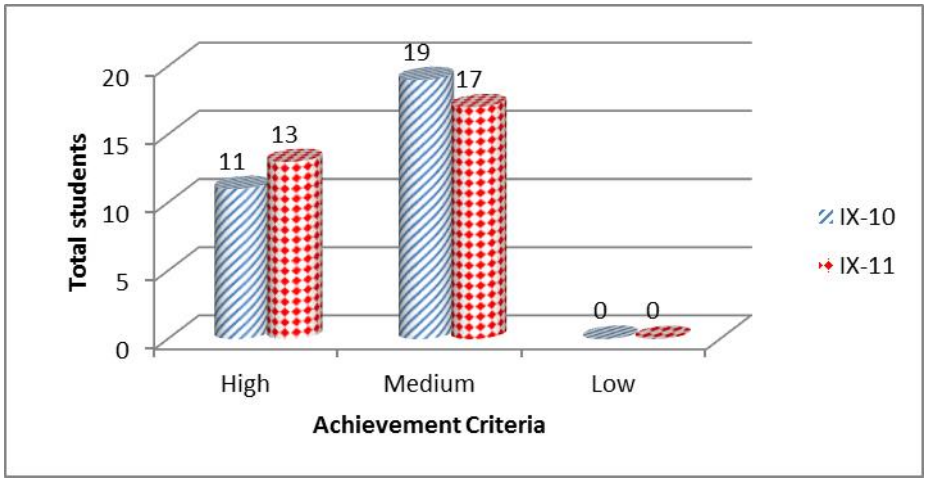

Figure 2. Graphic Criteria for Student N-Gain Achievement

Based on Figure 2, it can be seen that for class IX-10 as many as 11 high category students and 19 medium category students. Furthermore, for class IX-11 there were 13 students in the high category and 17 students in the medium category. Besides that in both classes there were no students in the low category.

To test the effectiveness of the treatment given in this study, a paired t-test was conducted on the results of the pre-test and post-test using the SPSS 20. The following are presented the results of the paired pre-test and post-test of students' critical thinking skills in Table 4.

Table 4. Pre-test and Post-test Paired t-Test Results
Paired Samples Test

		Paired Differences					T	Df	p
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	*Pre-test* IX-10 - *Post-test* IX-10	-53,5000	8,8474	1,6153	-56,8037	-50,1963	-33,121	29	0,000
Pair 2	*Pre-test* IX-11 - *Post-test* IX-11	-57,0000	8,3408	1,5228	-60,1145	-53,8855	-37,431	29	0,000

* $p < 0,05$

Based on the results in Table 4, information is obtained that an increase between pre-test and post-test can be seen at p <0.05, paired t-test results in both groups obtained p <0.05. So it can be concluded that Ho is rejected, it means that there is a significant difference between pre-test and post-test students'

critical thinking skills before and after the application of PhET-assisted inquiry learning model means that the post-test scores are higher than the pre-test scores. Therefore, it can be concluded that students in class IX-10 and class IX-11 after being taught using the PhET-assisted inquiry model results in better critical thinking skills compared to before using the PhET-assisted inquiry model.

Student activities during the learning process take place by observing student activities every five minutes. The mean analysis results from observing student activities during the learning process can be seen in Figure 3.

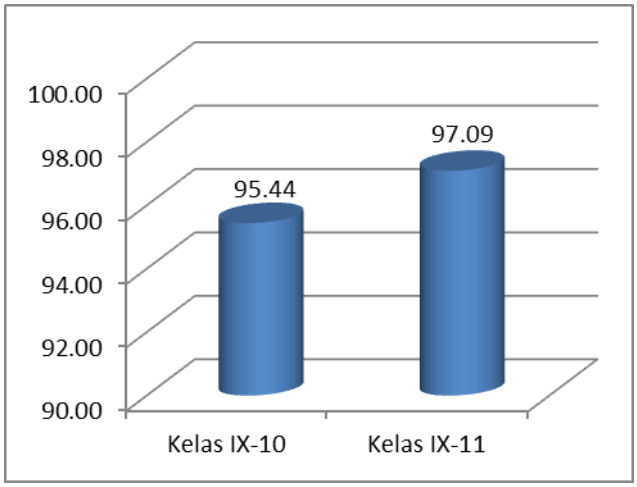

Figure 3. Graph of the average percentage of student activity

Based on Figure 3, the average percentage of student activity information obtained during the three meetings observed by two observers in class IX-10 was 95.44% and for class IX-11 was 97.09% and the categories were very good for both groups.

Student responses are students' opinions on interests, feelings of pleasure and renewal, as well as ease of understanding the components which include student textbooks, student activities in worksheets, the learning atmosphere, the way the teacher teaches and the learning methods used. Overall student responses can be seen in Figure 4.

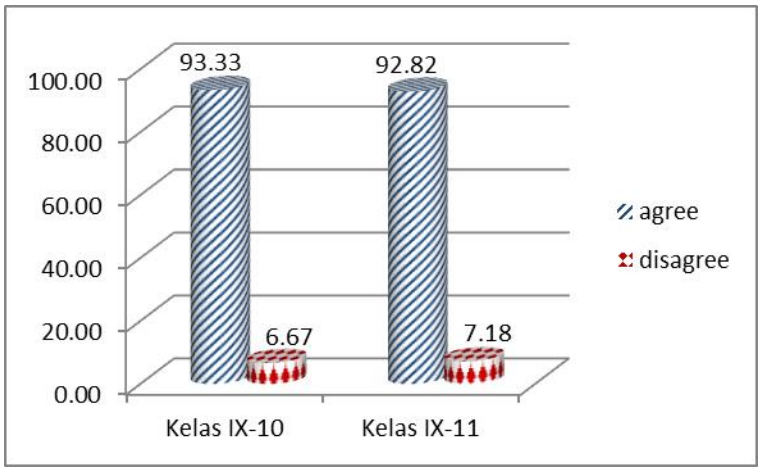

Figure 4. Mean Percentage of Student Responses

Based on Figure 4, information is obtained that the average results of the percentage of students' responses to the learning of the PhET-assisted inquiry model for the second class of the category are very good with each class obtaining an average percentage of 93.33% for classes IX-10 and 92.82 for class IX-11.

3.2 Discussion

The validity of the learning tools developed was based on the results of the validation of the learning tools carried out by experts including the syllabus, lesson plans (RPP), student textbooks (BAS), student activity sheets (LKS), and students' critical thinking skills test instruments before the learning device sets were used. Nieveen (1999) states that the learning model as a research product is said to be valid if it meets the content valid criteria and is construct valid.

The practicality of learning tools is measured based on the implementation of the learning plan and the obstacles encountered in implementing the learning. In principle, the implementation of learning is the ability of teachers to manage learning by using the learning model that is being used. With a practical learning model, in the learning process teachers and students will both be the subject of learning. The teacher is no longer a primary source of student learning, but being a teacher functions as a facilitator for student learning. This is in line with the opinion of Arends (2012) that by being guided by teachers who repeatedly encourage and reward them for asking questions and looking for solutions to real problems themselves, students learn to do this task independently later on. Furthermore Kek and Huijser (2017) states that it is important to provide feedback to students and feedback that is accompanied by references from being able to explain how the performance of each student in the group so that students' abilities can improve.

Students' critical thinking skills are seen by using the instrument of critical thinking skills test which is carried out twice, that is before learning is carried out using the inquiry learning model (pre-test) and after the learning process is carried out using the inquiry learning model (post-test). The students 'critical thinking skills test consists of 10 items of description, the test questions are arranged in accordance with the indicators of critical thinking to find out the students' critical thinking skills. According to Kardi (2002) and Ibrahim (2005) that by giving description questions to students, students are given sufficient freedom in terms of synthesizing and evaluating, their control is limited to efforts so that the questions can reveal the desired intellectual skills, and can be utilized if students are required to give an explanation, state the kinds of relationships, describe the data and formulate conclusions.

Based on the results of the pre-test and post-test analysis presented in Table 2 which shows that the results of the average pre-test scores for the two groups, these results appear that classically if present for the pre-test results get 0% which means that all students have not reached completion. Pre-test in this study was given to determine the initial abilities that students have in dynamic electric material. The initial ability of students regarding this dynamic electric material needs to be known by the researcher before conducting learning, because by doing so the researcher knows which indicators are already known and which have not been the initial test results indicate that all indicators have not been mastered. Therefore all indicators must be taught. This happens because students have not been taught dynamic electrical material and there is still minimal understanding of students related to the material to be taught, so their answers are based on their own knowledge or understanding. According to Wenno (2010) initial abilities are aspects possessed by students which are very influential in the selection of optimal teaching strategies to suit student characteristics. The initial ability is very important in increasing the meaningfulness of teaching, which then has an impact in facilitating the internal processes that take place in students when learning. The initial abilities of students can be measured through preliminary tests and

interviews. The pre-test results classically are inversely proportional to the results of the post-test which show a 100% completeness percentage classically, meaning that all students who take the PhET-assisted inquiry learning model can achieve or exceed the minimum completeness criteria set by the school that is with grades 70.

To find out the increase in critical thinking skills from the pre-test and post-test results in both groups, an N-gain score analysis was performed. The results of the analysis of N-gain values as presented in Table 3, the results in Table 3 show that there is an increase in critical thinking skills before using the PhET-assisted inquiry learning model to the results after using the PhET-assisted inquiry learning model for both groups. Based on the results in Table 3 it can be concluded that there is an increase in students' critical thinking skills from before (pre-test) and after (post-test) using a PhET-assisted inquiry model, in class students get an average N-gain of 0.61 with medium category for class IX-10 students and class IX-11 students get an average N-gain of 0.71 with a high category. Guidelines in determining the results of N-gain categorized as medium or high are in accordance with the opinion according to Hake (1999) which states that the value of N-gain is categorized high if it gets an N-gain result> 0.70, moderate category if it gets a result of $0.30 \leq$ N- gain ≤ 0.70, and low category if the N-gain results <0.30.

In Tebel 3 it can be seen that there are differences in the results of the average value of N-gain in class IX-10 and IX-11 students, as seen that class IX-10 obtains an average N-gain of 0.67 in the medium and class grades. IX-11 obtained an average yield of 0.71 in the high category. The difference in the average results of N-gain in the two classes is influenced by several factors including the understanding of the concepts owned by students of the material being taught, the level of difficulty of the questions, and the form of the questions. The form of the questions used in this study is to use a matter of description. By using the form of description problems, this requires students to answer every question that is done in accordance with the understanding of concepts owned by students. Although there are differences in the average N-gain results in the two classes, if compared then the difference is very small, this can be seen in Figure 2, in Figure 2 it appears that for class IX-10 there are 19 students categorized as medium, 11 students categorized as high , and for class IX-11 there are 17 students in the medium category, 13 students in the high category. Based on the results in Figure 1 seen in the two groups of students who are not categorized as low. Thus, it can be said that the results obtained by students as a whole are good, because there are no students in the low category in both groups. In addition, the results obtained as a whole are in the standard minimum completeness criteria set.

The increase in student pre-test and post-test results is supported by the opinion of Vygotsky (Nur, 2008) that students' cognitive changes occur if concepts that have been previously understood are processed through an imbalance in trying to understand new information.

Based on the results of the pre-test and post-test analysis in class IX-10 and IX-11, paired t test results are obtained to determine the effectiveness of the treatment given in this study as presented in Table 4 which shows that there are significant differences in the results of pre -test and post-test critical thinking skills of students before and after implemented using a PhET-assisted inquiry model, meaning that the post-test scores are higher than the pre-test. Therefore it can be concluded that students' critical thinking skills after learning by using a PhET-assisted inquiry model is better than before using a PhET-assisted inquiry model.

Besides that, based on the results of previous research conducted by Muzakki and Madlazim (2013) with the title development of science learning tools using PhET simulations to train junior / MTs students' science process skills in business and energy materials, showing an average student achievement of 77.29.This value has exceeded the minimum completeness criteria value of 65. Observed science process skills are basic process skills including observing, classifying, communicating, measuring, predicting and inferring. Achievement of the average value of students who exceeded the KKM score is the same as the

results of the development of learning models of PhET-assisted inquiry models that also indicate the achievement of achievement determined by schools.

Based on the results of previous research conducted by Thaiposri and Wannapiroon (2015) with the title Enhancing Students 'Critical Thinking Skills Through Teaching And Learning By Inquiry-Based Learning Activities Using Social Networks and Cloud Computing, shows that the results of the evaluation of accuracy improve students' critical thinking skills through teaching and learning with inquiry-based learning activities using social networks and cloud computing to be applied in real practice to obtain an average result of 4.6 and SD = 0.55 with a high category.

Furthermore, research conducted by Retnosari, Susilo and Suwono (2016) with the title influence of interactive multimedia-assisted guided inquiry learning model on critical thinking skills of class XI high school students in Bojonegoro Regency, shows that students who were given interactive multimedia-assisted guided inquiry learning did not differ significantly with students who were given guided inquiry learning and differed significantly from students who were given conventional learning. Students' critical thinking skills increased by 400.2% in the guided inquiry class, 416.8% in the multimedia guided assisted inquiry class and 334.4 in the conventional class. Increased critical thinking skills between the conventional-inquiry class by 16.4%, the conventional multimedia-inquiry class by 24.6% and the multimedia inquiry-class by 4.15%.

Based on the results obtained by the average response of students to learning in both groups categorized very well. This means that most students are very happy with the learning carried out using the PhET-assisted inquiry model. If students respond well, learning given using the PhET-assisted inquiry model is considered good for improving students' critical thinking skills on dynamic electric material.

According to Panjaitan (2016) another factor influencing students' responses to learning is the relationship between teachers and students. Students who feel close to the teacher will tend to participate in classroom learning activities. To build relationships with students, the way the teacher talks and behaves must reflect that the teacher respects and accepts the existence of students. The teacher must also ensure that each student gets the same treatment. During the learning process, students respond positively to the implementation and novelty of the learning model implemented in class.

Conclusion

Based on the results of the analysis of research data and discussion it can be concluded that the physics learning model of the PhET-assisted inquiry model that has been developed meets the valid, practical, and efficient categories.

1. The validity of the learning tools developed using the PhET-assisted inquiry model obtained an average validity of 3.65 categorized as very valid for syllabus with a percentage of 98.95%, 3.64 for the average validity results in the RPP categorized as very valid with a percentage 99.24%, 3.45 for the average results of validity in the valid categorized worksheets with a percentage of 99.24%, 3.55 for the average validity results in the student textbooks valid categories with a percentage of 98.72%, and 3, 54 for the average results of the validity of the critical thinking test instrument categorized as valid with a percentage of 96.47%.

2. The practicality of the developed learning tool can be seen from the implementation of the lesson plans obtained by each class, namely class IX-10 which obtained an average score of 3.51 in the good category, and 3.47 for the average score of assessment in grade IX-11 students with good categories.

Constraints during the learning process can be overcome, the first students have difficulty in carrying out the phet-assisted experimental procedure on the worksheet so that the solution is to provide direction and guidance to students about the work procedures on the worksheet and provide guidance on the use of the PhET media, secondly there are still some students who do not read the work steps in the worksheets, so that in learning the teacher is still heavily involved so the solution is to ask students to read every work step in the worksheets carefully while doing activities, so the teacher is not too much involved, and the third time required in carrying out learning activities beyond the time allocated so the solution is to reorganize the time allocation so that all learning activities are carried out, and increase the time allocation if possible.

3. The effectiveness of the developed learning device can be seen from the increase in N-gain student test results in both classes, class IX-10 obtain an average score of N-gain of 0.67 in the medium category and for the results of N-gain in class IX-11 namely 0.71 in the high category. Student activities during the learning process in both classes are very good with a percentage of student activity 95.44% for class IX-10 and 97.09% for class IX-11 students. Very good student responses to the learning process of PhET-assisted inquiry models in both classes was very good with an average percentage of 93.33% for class IX-10 and 92.82% for class IX-11 students.

For this reason, it can be said that the learning device developed is appropriate to be used to improve junior high school students' thinking skills on the subject of dynamic electricity.

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