



Journal of Science Education Research

Journal homepage: www.journal.uny.ac.id/jser



The Effectiveness of the Application of PhET with Inquiry Learning Model to Improve Understanding of the Concept

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Keywords

PhET Simulation, Inquiry learning, Understanding of concepts

Abstract

PhET has many benefits as a means of instructional technology and media in the learning process, especially in Natural Sciences (IPA) subjects that require experimental activities. The study aimed to determine the effectiveness of using PhET simulations with inquiry learning models to increase students' conceptual understanding of static electricity. This type of research was quasi-experimental with a posttest-only control group design. The subjects were students of class IX at Public Junior High School (SMPN) 1 Tebing Tinggi for the 2022/2023 academic year. Data collection used concept comprehension question sheets that had been prepared by indicators of conceptual understanding and indicators of competency in static electricity material. The study showed the average value of the indicator in the experimental group was higher than the control group. This study concludes that learning using the inquiry learning model assisted by PhET simulation can facilitate students to learn independently, and students can conduct virtual experiments as an alternative solution to the limited facilities of the schools.

INTRODUCTION

Education is the main element that can affect national development, and the development of a country (Samiun and Nurhayati, 2022). In science lessons, learning activities are not only conducted in the classroom but also the laboratory, playing an important aspect to support learning (Dian and Euis, 2022). Science lessons with laboratory activities can increase understanding of concepts and mastery of students to argue (Basuki, 2021).

Science is a redundant expression that includes scientific products such as laws, theories, and concepts as a result of stages and scientific attitudes (Sulistijo et al., 2017). Science subjects in Junior High School have a goal to guide students to understand several concepts from science subjects, which are to be implemented to solve a problem in real life (Dede et al., 2018). Understanding the concept of the science lesson is very important for the students so that they can easily understand each of the natural phenomena occurring around or in their environment (Suhartono et al., 2019; Anderson & Krathwohl, 2016). For students to have an understanding of a particular concept, therefore the activity of teaching and learning activities must

involve the role of students in an active way (Yolanda et al., 2019).

The mastery of Science and technology at this time is an important key in facing the challenges and obstacles in the future era. The 21st century has brought a paradigm shift in curriculum, media, and technology (Rengganis, 2023). One of the changes that occurred was the shift from conventional learning to technology-based learning (Yusuf, Widyaningsih, & Purwati, 2015).

Learning is a process of collaboration between students and educators or teachers in using their abilities and resources (Diana et al., 2022). Static electricity material is a science lesson that requires practical activities in the laboratory. Various kinds of demonstration and practical activities can not all be conducted in a real way in the laboratory, so this makes the existence of an obstacle to the implementation of these activities. And, the availability of time is also an inhibiting factor (Basuki, 2021).

So far, science learning is often presented as a collection of equations that are a form of simplification of reality (Wegener, McIntyre, &

McGrath, 2012) or what we often know as traditional learning. This traditional learning is still practiced by using teaching materials that are still quite difficult to access at every time setya in every location (Astra, Nasbey, & Nugraha, 2015). The laboratory was built to facilitate students in experimenting (Niliyanti, 2021). But in reality, not all schools can provide provision for existing laboratories, especially in schools in rural environments (Azani, 2022).

Research on innovation in science learning, emphasizes the activities of teaching and learning that focus on students, but traditional learning is no longer relevant at this time (Ekmekeci & Gulacar, 2015). Static electricity material that has abstract properties and is also not visible, of course, requires a good and appropriate method to explain which aims to avoid the error of a concept (Mursalin, 2013). One of the best and most effective ways is by using a PhET application program. In the Phet application, the experiment of static electricity provides a wide range of components that are fairly complete. And, it is very easy to do a simulation with attractive colors. Various components in PhET applications can be assembled very quickly and easily. Therefore, students can conduct experiments to strengthen their mastery of concepts in static electricity material.

Learning Media is one of the important components in the field of Education. The Learning Media needed at this time is a learning media that focuses on empowering students, is fun and fair, and also awakens the spirit of learning during the learning stages through the material being taught (Hasna Qonita, 2016). Choosing learning media must be based on the needs of the students, suitability with the purpose of teaching and learning activities, learning materials, and learning methods. One of the four bases must be the basis for choosing a learning medium.

The use of media will be effective and liked by students when meets the students' needs, according to the targets and goals of learning, the material to be given, and the methods determined by the teachers (Hadi, 2017). There are various types of media. First, print media includes modules, books, and worksheets. And, electronic media includes audio, video, and multimedia presentations. Also, it may use online or online content such as simulation Phets, websites, and others (Shintya Azzahra, 2022).

PhET is an example of the use of a Virtual computer lab. Phet Virtual Lab can be used either offline or online. PhET is made by the University of Colorado, United States, and can be accessed through Tablet devices, computers, and smartphones for free. (Inayatun, 2021). Internet Media has a fairly important role in increasing the

interest in learning for students (Devi, 2018). The advantages of Phet simulation are that it can be used as an approach to teaching and learning activities that require interaction and involvement with students, educating students to have constructivism thinking patterns, where students combine the initial knowledge they have with various virtual findings from the simulation they are running, making teaching and learning activities much more interesting, as well as to visualize the various concepts of Science with the form of a real model (Sari et al, 2013). The weakness of this PhET simulation is that some of the simulations are still only available in English and require additional applications to run (Defianti et. al, 2021).

Using PhET media has advantages, such as it does not require real tools and materials, accessed at any time with no time limit, used anywhere, and simulate material that has abstract properties (Athallah et al., 2017). The use of virtual laboratories can provide an interactive experience for students to find the concept by way of activities about exploring data objects and phenomena (Hikmah et al., 2017).

The use of PhET in practical activities is not bound by time and has the freedom to decide the location. Then, it can increase the understanding of the material better than in the classroom (Martínez Borreguero et al., 2011). The use of Phet simulation as a learning medium that can increase the understanding of the concepts of students in science subjects is very relevant to use and also by the century of technological development that exists at present. (Irma Yulia et al., 2018). The use of attractive learning media can also give an impression and an impressive effect on learning because students will not be dependent on what is conveyed by the teacher (Marwa et al., 2020)

PhET has theoretical and experimental simulations that actively engage users. Phet simulations can display physics animations that have abstract properties or cannot be seen visibly, such as electrons, atoms, magnetic fields, and photons. In addition to building concepts, PhET can be used to bring skills to the stages of science (Susilawani, et al., 2022).

Concept understanding is an ability possessed by students to understand various concepts after teaching and learning activities (Lin Suciati, 2017). Understanding the concept of students can be improved with the use of Phet simulation-based inquiry learning because it involves the active participation of students in finding their concepts, learned using practical activities (Yuliyanti et al., 2016; Malahayati & Saminan, 2016). Inquiry learning is an approach of learning activities involving stages of investigation of nature and natural materials to answer questions and make a

discovery through investigation to get an understanding. (Nurafni, 2022).

According to the research by (Yulisa Murnilasari et al., 2021), the virtual laboratory is a method, and at the same time, a good and appropriate media. According to technological developments, it is easy to understand and also be used as one of the learning alternatives in leading to success that is by the target and the desired goal, namely.

The inquiry learning Model emphasizes an effort to maximize the activities of the students, then the students can find the answer on their own from a questionable matter until the student can explore the potential that is in him. (Nurafni et al., 2022). One of the learning models that can provide opportunities and opportunities for students can understand a concept is the inquiry learning model (Susilawani, et al., 2019).

Inquiry learning is designed to invite students directly into a scientific process in a relatively short time. The application of the inquiry learning model places much more emphasis on the activities of the students carried out in a maximum way to train critical thinking skills to improve the results of the students' learning (Susilawati, et al., 2019).

Various stages of inquiry learning require students to get involved in an active way at the teaching and learning stage. The stages of inquiry learning include orientation, formulating hypotheses, formulating problems, testing hypotheses, collecting data, and formulating a conclusion (Wina Sanjaya, 2011). Each of the stages in the inquiry must continue to be observed by educators, especially those related to the wishes of the students, student involvement, encouraging students' power, and building the student's confidence (Nurafni et al., 2022).

The application of the inquiry learning model assisted by PhET simulation can improve the understanding of concepts from students (Puspitaningtyas et al., 2021; Rais et al., 2020). PhET provides experience in conducting abstract experiments with various kinds of animation (Hooked, et al., 2014).

RESEARCH METHOD

The research used a quasi-experimental method. The experimental method is a quantitative research method used to determine the effect of the independent variable on the dependent variable (result) in controlled situations and conditions (Sugiyono, 2018).

This study used a posttest design-only control design to measure student's understanding of the concept. The posttest-only control design Formula is shown in Figure 1.

X	O ₂
-	O ₄

Figure 1. Posttest Only Control Group Design

The population was all students of classes IX at SMPN 1 Tebing Tinggi in the 2022/2023 school year, which consists of 5 classes with a total of 143 students. The research sample is part of the population taken as a data source and also represents the entirety of all populations, up to the population that has taken only 2 classes, namely as a control and experimental class.

The sampling techniques of the research were by looking at the scores of students' daily tests to the previous material, namely the material inheritance properties. Also, it used the data in the homogeneity and normality test. The subjects were 25 students in Class IX-1 playing as an experimental class and 27 students in Class IX-2 playing as a control class. They are in the odd semester of the 2022/2023 academic year. The preparation of the concept understanding test refers to three indicators of concept understanding and cognitive processes, referring to Bloom, including translation, interpretation, and extrapolation.

The translation indicator is the first indicator of understanding the concept. In this indicator, students are trained to translate data, process data from the form of Tables converted into graphic form, and explain the data in verbal or word form.

The second indicator of understanding the concept is interpretation. In this indicator, students are trained to process data, predict, and calculate data obtained through practicum results through PhET simulations with the aim of testing hypotheses. Then, the students can find concepts independently and confidently.

The third indicator of understanding the concept is extrapolation. In this indicator, students are trained to conclude the data analysis. This activity trains cooperation between students in study groups, a sense of responsibility honesty, and confidence.

The data of the research consisted of primary and secondary. Secondary Data is taken from the daily test data of science in class IX-1 and Class IX-2 of the previous material. Meanwhile, the primary data is taken from the test scores of students' understanding of the concept that is adjusted to the indicator of concept understanding after learning.

The research used two kinds of instruments, including learning tools and instruments in data collection. Learning tools are tools, materials, instructions, media, references, or guidelines of the learning stage. The learning tools of the study were

a syllabus, a learning implementation plan (RPP), and a student worksheet (LKPD).

LKPD is a means to facilitate and help learning activities to build an effective interaction between teachers and students and can increase the achievement and learning activities of the students. The preparation of LKPD has benefits for students and educators. The advantage of using LKPD for educators is that it can facilitate the implementation of learning activities. And, the benefits for students are independent learning, understanding the lessons very well, and carrying out tasks in writing properly and correctly.

The instrument for data collection on students' understanding of concepts at the science learning stage, especially in static electricity material, uses objective questions that are arranged according to the indicators of understanding concepts. The preparation of the test of understanding concepts refers to Bloom with three categories and cognitive processes and understanding of concepts, namely translation, interpretation, and extrapolation.

Learning tools, LKPD sheets, and instruments for understanding concepts are validated by 3 validators. Then, it is validated twice in the validation stage to obtain a valid device. The validation results are descriptive analyses based on the average score of each indicator that has been validated. Validation is done by using Likert scale research. Calculating the validity of each device adjusted to the validity category can be found by looking at the Table 1.

Table 1. Likert Scale Validity Categories

No.	Interval	Validity Level
1.	3,41 – 4,00	Strongly Valid
2.	2,81 – 3,40	Valid
3.	2,01 – 2,80	Poor
4.	1,00 – 2,00	Invalid

Data collection techniques were by collecting secondary data and primary data. Secondary data of the initial observation is the value of UH IPA students in the previous material. Furthermore, the secondary data was obtained from the normality test and homogeneity test with the help of the application program SPSS 23. Primary Data were collected by providing instruments for understanding the concept of students at the end of the meeting to the experimental and control classes. The control Class is treated with a Direct Learning learning model without PhET simulation, while the experimental class is treated with an Inquiry Learning Model with PhET simulation.

Data analysis techniques used two kinds of analysis, namely inferential and descriptive analysis methods. The descriptive analysis method is used to perform data analysis by describing and

representing the collected data as it is without intending to make a conclusion that applies to the public. The inferential analysis method is an analysis method that aims to compare data. Inferential analysis uses formulas specifically for calculation results that serve as the basis for generalizing and making a policy or decision. Inferential analysis methods are divided into two types, namely correlation research and experimental or comparative research.

The research used multivariate Analysis of Variance (MANOVA). At first, the homogeneity of the data was tested with the Levene test. The first test used SPSS 23. The basis of decision-making is if the probability value >0.05 , then the data is homogeneous, and vice versa if the probability value <0.05 then the data is not homogeneous. After the homogeneity test, several test requirements must be met.

Data from the test results of understanding the concept of students is analyzed by giving a score to each item. The correct answer to the question is given a score of 1. And, the incorrect answer to the question is given a score of 0. This technique is used to determine the percentage of students at each level of understanding by using the formula:

$$NP = \frac{R}{SM} \times 100\%$$

Categorization the students' concept understanding from the test results using the criteria in Table 2.

Table 2. Interval Category Concept Understanding

No.	Interval (%)	Category
1.	$90 < x \leq 100$	Very High
2.	$80 < x \leq 89$	High
3.	$65 < x \leq 79$	Medium
4.	$55 < x \leq 64$	Low
5.	$0 < x \leq 54$	Very Low

RESULT AND DISCUSSION

The implementation of teaching and learning activities carried out in six meetings given treatment with inquiry-based learning LKPD assisted Phet simulation containing indicators of interest in learning and understanding of concepts. The first meeting was on electric charge material with time allocation (2x40'), the second meeting discussed the topic of Coulumb's law with time allocation (3x40'), the third meeting discussed the topic of electric field with time allocation (2x40'), the fourth meeting discussed the topic of electric potential with time allocation (3x40'), the fifth meeting, and the last meeting is the evaluation of static electricity material. The first step is to provide a questionnaire of learning interests to students.

Then, it continues providing a concept understanding test instrument totaling 15 questions.

In this activity, the students were divided into four study groups. The first step in the learning stage with a simulated PhET-assisted learning Inquiry model is Orientation. In the orientation stage, the teacher conditions so that the students are ready for the teaching and learning stages. Here, the teacher invites the students to pay attention to the orientation of the problems in the LKPD given to each group. The LKPD given has Phet simulation-assisted work steps and contains indicators of understanding concepts, and indicators of interest in learning with the stages of inquiry learning.

The second stage is formulating a problem. At this stage, the teacher facilitates and guides the students to understand and formulate a real problem of the LKPD sheet. The problem is presented in a way that is quite good and interesting, like a picture, demonstration, and also in the form of discourse to challenge students to perform the search and formulate it. The question is written in the column formulation of the problem on the sheet LKPD. And, the question must be answered on their understanding.

The third stage is that the students make an answer or a temporary hypothesis from the questions on the LKPD sheet. The teacher acts as a facilitator in the classroom guide and directs students in making temporary answers and writing in blank columns on the LKPD sheet. Temporary answers related to material or concepts that are being studied by students will be proven true after conducting experiments or practicum using PhET applications to obtain data, in which it will be analyzed.

In the fourth stage, students collect data in groups by conducting experiments using Phet simulation that will produce data. At this stage, it takes quite a long time compared to the time it has determined due to inadequate internet network conditions, long-loading laptops, and even some students who cannot operate computers.

The fifth stage is to test the hypothesis. In this stage, teachers guide students in answering various questions on the LKPD sheet. At this stage, it trains the rational ability of the students where the hypothesis that has been made will be tested by way of comparison of the data from experiments through Phet simulation. This stage also trains the attitude of honesty and confidence.

The last stage is the conclusion. The teacher guides the students in the stage of describing the findings obtained based on the results of the hypothesis, testing by an educator in terms of guiding the students to reach an accurate conclusion.

Learning is done by using the PhET-assisted Inquiry Learning model that can make students directly apply static electricity material. And, teaching and learning activities become much more interactive and also fun for students and provide ease of understanding the material and draw conclusions from various concepts contained in the material. The purpose of making the interactive simulation application program is to "help students visually understand concepts, ensure educational effectiveness and usability." The first is to assist students in visualizing a concept completely and clearly and ensure efficient and effective education and continuous usability (Yuniar, Haris & Amin, 2015: 75).

The results of the posttest concept understanding of students were carried out intending to obtain the value of the control group and the experiment after giving a treatment. The form of the test used is an objective question of 15 questions. The results of the average value of the posttest concept understanding of the control group and the experiment are assessed using the criteria of the Table 3.

Table 3. Concept Understanding Posttest Data

Category	Posttest Value	
	Experimental class	Control Class
Top Rated	93	87
Lowest value	53	33
Number of students	25	27
Average	80	72

Descriptive analysis of students' concept understanding score using SPSS 23 is presented in the Table 4.

Table 4. Descriptive Data of Concept Understanding

	Descriptive Statistics Pemahaman Konsep				
	N	Min	Max	Mean	Std. Dev
Experimental class	25	53	93	79,92	12,616
Control Class	27	33	87	72,15	15,657

Table 4 describes the data on concept understanding for experimental classes that apply the inquiry learning model with PhET-assisted simulation of 25 students and the control class of 27 students. The average value of students' concept understanding or Mean post-test for the experimental class was 79.92, while the control class post-test was 72.15. Therefore, descriptive statistical analysis can conclude that there is a difference in the average understanding of the students' concepts of students between the control class and the experimental class.

The next stage will be the final condition of the MANOVA test (Post-Test) to determine the multivariate analysis test (MANOVA). The results of hypothesis testing using multivariate tests are presented in the Table 5.

Table 5. Result of Hypothesis Test of Multivariate Analysis Test (MANOVA)

	Effect	Sig.
Intercept	Pillai's Trace	,000
	Wilks' Lambda	,000
	Hotelling's Trace	,000
	Roy's Largest Root	,000

- a. Design: Intercept + Class
- b. Exact statistic

Table 5 is a multivariate test Table that explains the comparison test taken from the average of the components associated with understanding

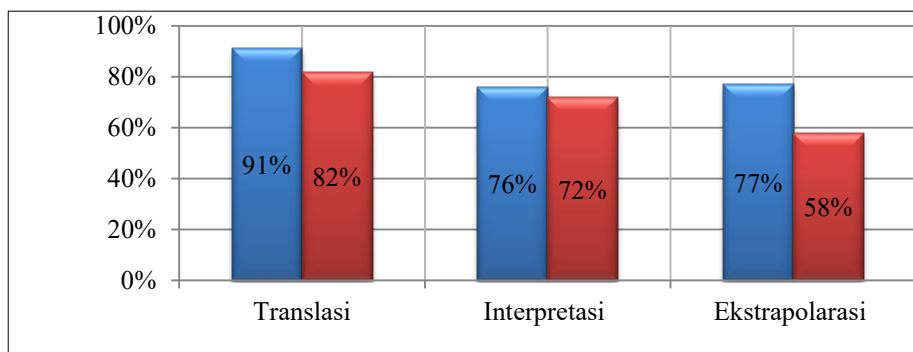


Figure 2. Concept Understanding Chart

In Figure 2, the control and the experiment class have differences in the students' concept understanding on each indicator. In the translation indicator, students are trained to present data in the form of graphs, Tables and analyze data from the results of experiments, and declare the results of experiments into words or verbal form. The understanding of concepts in the experimental class is much higher when compared to the control class. The experimental class obtained an average score of 91% at a very high category level and the control class had an average with a percentage value of 82%. This illustrates that the inquiry learning model-based LKPD-assisted PhET has a very important role in the process of teaching and learning activities due to the increase in activities carried out by students and also helps educators in guiding students to find a concept in a way through activities independently (Wulandari, 2013).

In the control class, the students are less involved directly in the activity of data collection and processing the data from a number into a graph and from the graph into a conclusion in the form of words or sentences. In the control class, students do

the concept and also the interest in learning from the students with the treatment (control class and experiments). There are statistical tests, namely Wilks' Lambda, Pillai's Trace, Roy's Largest Root, and Hotelling Trace. The results of significant treatment by Wilks' Lambda procedure, Pillai's Trace, Roy's Largest Root, and Hotelling Trace obtained significant values with a value of 0.000 is $0.000 < 0.05$ which corresponds to the criteria that H_0 is rejected and H_a is accepted. Therefore, the independent variables of the Phet-assisted learning inquiry model simulation showed an influence on the dependent variables as the understanding of concepts and also the interest in learning from students in the final condition (Post-Test).

A comparison of concept understanding between control and experiment classes, according to indicators of concept understanding, is presented in the Tables and graphs in Figure 2.

not practice directly related to the material of learning. Then, reading the graph is one of the difficulties in solving a problem.

The second indicator of understanding the concept is interpretation. This indicator trains students to make an appropriate limit on interpreting data. Understanding of the concept of experimental class on interpretation indicators reached an average of 76% in the medium category. Meanwhile, the control Class reached an average of 72% in the medium category.

This shows that the control and experimental groups can be interpreted well and equally. Using LKPD inquiry-based learning-assisted Phet simulation helps students in predict, interpret, and calculate data. The inquiry learning model involves students and trains students to predict temporary answers from the problem formulation proposed in the problem formulation column listed on the LKPD.

Students in the experimental class are involved in interpreting the correct answers to the questions listed on the LKPD to test hypotheses. While in the control class, the students participated in the

discussion process and questions and answers between fellow students and teachers as a reinforcement of the results of the discussion. Students in the control and experimental classes can interpret and calculate the data obtained from the experimental results using PhET for the experimental class. Meanwhile, the control class from the data provided by the teacher performs calculations using formulas that have been obtained from concepts in related materials.

Activities of students in the experimental class at the testing stage, the hypothesis of students involved active and cooperate in working on LKPD. LKPD is a means used regarding teaching and learning activities to help ease the students to understand the material and also improve the students' activities (Khofifah, 2022). The results of research by Fadilah (2018) suggest the learning activities carried out with the help of LKPD make students independently find concepts.

The third indicator of the concept understanding is extrapolation. This indicator trains students to state effectively a conclusion. The experimental class in extrapolation indicators reached an average percentage of 77% with the medium category. Then, in the control Class, it reached an average of 58% in the low category. This shows that the understanding of the concept of extrapolation indicators in the experimental group is higher than in the control group.

In learning activities in the experimental class, students are involved in drawing conclusions written on the LKPD sheet and then the experimental data obtained from PhET simulations are presented in front of the class. This makes the students much more diligent and active in finding and drawing the right conclusions by discussing with the fellow in the group.

After presenting, the students who act as the audience are allowed to add or give feedback and refutation so that the discussion process runs actively and is conducive to this activity can produce a more satisfactory conclusion. Meanwhile, in the control class, the conclusion process is carried out by summing up the material provided by the teachers and the question and answer process in the classroom during the learning. However, there are no experiments or practices in the control class so this indicator is still not successful. This shows that the use of simulation Phet-assisted LKPD is very helpful in the process of training students to predict and conclude.

PhET simulation is an interactive simulation that aims to increase the involvement of students in learning. PhET simulation is very helpful for students in building an understanding of the concept, making the learning atmosphere more

interesting with the animations providing a learning experience. Phet simulation prioritizes the linkage between reality and basic science, provides feedback, supports interactive and Constructivist approaches, and facilitates creative workplaces (Prihatiningtyas et al, 2013).

The rapid development of technology has had a significant impact on several sectors, including the education sector. Technological developments will have a positive impact on the learning process if used with the right design so that the achievement of learning goals can be carried out and achieved (Diana et al., 2022). The use of Phet-based learning media is one of the activities that can improve students' understanding of concepts.

One of the easiest learning innovations to implement is the use of computers. The implementation of learning using computers can improve the quality of learning because it helps visualize abstract ideas, facilitate understanding of the material, display learning materials to be more interesting, and allow interaction between learning and the material being studied (Choiron, 2013).

The learning inquiry Model and the use of the simulation PhET application are more structured and organized when teachers use LKPD-based learning inquiry models and PhET with the aim of more efficient use of time and learning objectives are easy to achieve by students.

The evaluation in this study is whether it has been implemented successfully and by expectations. The validation results of learning tools such as lesson plans, LKPD, and instruments for understanding the concept as a whole are considered valid and feasible to use after two validations and improvement processes by three validators. At the implementation stage, before students use Phet simulation in the learning process, the teacher should explain in advance how to use which aims to anticipate students who are not familiar with Phet simulation. So, it is hoped that students better understand and easier to perform activities and follow instructions in learning activities.

CONCLUSION

Based on the research, data processing analysis and discussion concluded that the model of Inquiry Learning Phet-assisted Simulation on static electricity material by arranging learning tools such as lesson plans and LKPD refers to the inquiry learning model is valid and feasible to use in the learning process in schools. The average score of interest in learning and concept understanding in the experimental class was 74 with the strong category and 80 with the high category, while the

control class was 71 with the strong category and 72 with the medium category.

Based on the data analysis, the results of the concept understanding test were on the three indicators, namely translation, interpretation, and extrapolation. The experimental group had higher average values compared to the control class. Based on the data processing analysis and discussion, it concluded that the PhET application with inquiry learning model on static electricity material is effective for use in schools because can achieve learning objectives.

Research shows that the use of PhET applications with an inquiry learning model is effective in improving the student's concept understanding. The research suggests that using the PhET application urgently needs to maintain network stability so that learning can run smoothly and conducive. Also, further research may be conducted using PhET applications with different learning models and other science materials.

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