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The Effect of Using Virtual Laboratories Using the Guided Discovery Learning Model on Students' Conceptual Understanding of Static Electricity Material

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Abstract: This study aims to test or examine the effect of the use of virtual laboratories using the Guided Discovery Learning model on students' conceptual understanding abilities in static electricity material. This type of research is a quasi-experimental study with a nonequivalent control group research design. The population in this study were all students of class XII of SMAN 1 Monta. The sampling technique used in this study was purposive sampling with class XII MIPA 2 consisting of 28 students as the experimental class and class XII MIPA 1 consisting of 28 students as the control class. Before and after the treatment, both classes were given a conceptual understanding ability test in the form of essay questions that had previously been tested for their feasibility with validity, reliability, difficulty level of questions, and discriminatory power. The results of the initial test (Pretest) and final test (Posttest) of conceptual understanding ability were analyzed for homogeneity and normality to conduct a hypothesis test. The analysis of the hypothesis test using the t-test obtained a t_count of 3.49 and a t_table of 2.00. Thus, the calculated t_value is greater than the t_table, so H_0 is rejected and H_a is accepted, so it can be concluded that there is an influence of the use of virtual laboratories using the Guided Discovery Learning model on students' conceptual understanding abilities in static electricity material.

Keywords: Conceptual understanding; Guided Discovery learning; Static electricity; Virtual laboratory

Introduction

In the 21st century, science and technology are developing rapidly, requiring society to be able to keep up with the challenges of this era (Haleem et al., 2022). According to Mesterjon et al. (2022), in the era of the Industrial Revolution 4.0, many fields have been affected by technological developments, and education is one of them. Education is a field that utilizes technology as a simulation and learning resource. In the field of education, the Industrial Revolution 4.0 greatly assists the role of teachers in carrying out teaching duties in the classroom, such as the ability and readiness of teachers in teaching, such as preparing and planning interesting learning models and methods to focus students' attention. This requires teachers to always update information in choosing learning models or methods in order to further improve the quality of education. As with science learning, almost all materials require experimental activities to support the achievement of learning objectives.

According to Hadzigeorgiou et al. (2019) and Corni et al. (2020), until now, science subjects, especially physics, still have little place in the minds of students. Physics is considered a difficult and unpleasant subject. Teachers also use various methods to make physics

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subjects more interesting and enjoyable so as to motivate them to learn physics. As a subject that studies natural phenomena, physics learning must not only emphasize mathematical abilities, but also be oriented towards understanding physical phenomena and based on learning experiences. Learning that provides many meaningful learning experiences can be done through laboratory experiments. Physics learning with the help of practical work will encourage students to build more meaningful concepts by connecting experimental results with materials that students already have (Cai et al., 2021; Parker et al., 2022; Almulla, 2020). Students who have mastered concepts through the scientific process through laboratory practical activities will be able to solve the scientific problems they face (Kranz et al., 2023; Hutapea et al., 2021).

Based on the results of an interview with one of the physics teachers at SMAN 1 Monta, the researcher received information about obstacles, namely the absence of practical activities and the lack of facilities and infrastructure such as laboratory equipment, which can hinder the fulfillment of KD which requires practical content. In addition, the results of filling out the questionnaire carried out by students at SMAN 1 Monta showed that most students think that physics is a difficult subject and has many formulas. There are many causes that cause this situation, for example, learning in schools that still apply conventional models, namely peer tutoring and lecture learning models, so that learning outcomes are less than satisfactory. Efforts are needed to equip students with a comprehensive understanding, such as through the use of technology and information in the form of interactive media and the selection of appropriate learning models (Marpanaji et al., 2018).

Due to limited facilities and infrastructure, one solution is to carry out practical activities virtually, so that students still feel the relevance of their studies or as an alternative to real practical work (Stoian et al., 2022). Virtual practicums are activities within the scope of the laboratory that are presented in the form of software. This virtual practicum also requires a laboratory that is also virtual or in this case often referred to as a virtual laboratory (Setiawan et al., 2024; Chan et al., 2021). Virtual laboratories provide a simulated version of a traditional laboratory for student-centered learning. The use of virtual laboratories contributes to the learning process by providing opportunities for students to learn while working, stimulating student interest, providing interesting activities that encourage discovery, and ensuring active class interaction through discussion (Hellín et al., 2023; Capone, 2022).

According to Nainggolan et al. (2023) and Felita et al. (2023), and Rahmawati et al. (2020), physics is a difficult subject for students, so many experience misconceptions in learning physics, especially static electricity. In line with research conducted by Devy et al. (2022) students do not understand the concept of physics and the level of physics misconceptions of students at SMAN 9 Pontianak is quite high with an average physics misconception of 77.36%. Static electricity is one of the materials in the Physics subject and in learning Physics, especially Static Electricity, many students still have difficulty understanding Static Electricity material. In addition to learning methods and media, choosing the right model is also needed to improve students' conceptual understanding.

One of the innovative learning models that is believed to be able to improve students' understanding of physics concepts is the Guided Discovery Learning model (Wafa & Jatmiko, 2022). According to Muhali et al. (2021), the guided discovery learning model can improve cooperation between students through investigations in research, improve students' understanding of learning and improve creativity and critical thinking skills. Based on the problem of physics which is still seen as a scary subject, there are many formulas or equations that must be memorized, and students have not found the meaning of what is being learned. This will have an impact on students' conceptual understanding, so the author plans to conduct research using a virtual laboratory to improve students' conceptual understanding of static electricity material.

Method

The type of research conducted is Quasi Experiment research. Quasi-experimental research is an experiment that has treatments and impact measures (Gopalan et al., 2020). The research design applied in this study is a non-equivalent control group design. The research was conducted at SMAN 1 Monta in the 2023/2024 academic year. The population of this study was all students of class XII of SMAN 1 Monta, totaling 3 MIPA classes. The sampling used was purposive sampling, so that two research classes were obtained, namely class XII MIPA 2 as the experimental class totaling 28 students and class XII MIPA 1 as the control class totaling 28 students. Class XII MIPA 2 was given treatment with a virtual laboratory using the guided discovery learning model while class XII MIPA 1 used a conventional model without a virtual laboratory. Before being given treatment to both classes, students were given a pretest first which aimed to determine the initial abilities of students.

Then after being given treatment, students will be given a posttest to determine the ability to understand the concept of students after being given treatment. The test used was a cognitive test in the form of an essay. The validity of the research instrument was tested to determine whether the data obtained was valid or not, reliability was aimed at determining the level of trustworthiness of an instrument, the level of difficulty was aimed at determining the ability of students to answer correctly, and discrimination was aimed at being able to distinguish between students with high abilities and students with low abilities (Van De Pol & Oudman, 2024). The data analysis technique used to determine the effect of using a virtual laboratory using the guided discovery learning model used the t-test polled variance hypothesis test with a significance level of 0.05. Before the hypothesis test was carried out, the prerequisite analysis test was first carried out, namely the homogeneity test, the normality test using the Chi Square test (χ ^ 2) and the N-gain score test.

Result and Discussion

This study aims to determine the effect of using a virtual laboratory using a guided discovery learning model on students' conceptual understanding of static electricity material. This study is a quasi-experimental study conducted by providing treatment in the form of a guided discovery learning model using a virtual laboratory in the experimental class, namely class XII IPA 2 with 28 students and treatment in the form of conventional learning in the control class, namely class XII IPA 1 with 28 students. Both classes were given treatment for four meetings with a time allocation of 90 minutes for each meeting (2 teaching hours). Guided discovery model learning using virtual laboratory media, namely PhET (Physics Education Technology) and Go-Labs (Global Online Science Labs) increased the level of students' conceptual understanding.

Table 1. Results of Validity Tests and Reliability Tests

Number of Students	Valid	Invalid	r_{11}	r_{tabel}
28	9	7	0.70	0.37

This is because the guided discovery learning model used directly involves students' abilities to search for and find problems themselves systematically, critically, and logically. This is in line with research from Noer et al. (2020) and Akina et al. (2023) which states that discovery learning through guided discovery learning can improve students' high-level thinking skills in terms of critical thinking, creative thinking, analytical thinking, and concept mastery. In addition, research conducted by Darling-Hammond et al. (2020) and Lestari et al. (2021), concluded that learning devices designed with the guided discovery learning model have a positive effect on cooperation skills and concept mastery. Based on the instrument trials that have been carried out and analyzed with validity tests, reliability tests, difficulty level tests, and discrimination tests, the results can be seen in Table 1 and Table 2.

Based on Table 1, the results of the instrument trial show that out of 16 questions submitted, 9 questions are valid and 7 questions are invalid. Meanwhile, the results of the reliability test obtained r_11 were 0.70 while r_table was 0.37. Based on the calculation results, it can be seen that r_11 > r_table so that the 16 questions are said to be reliable.

Table 2. Results of the Difficulty Level Test and Differential Power Test

	Difficulty Level Test		
Number of Questions	Easy	Currently	Hard
16	9	6	1
Differential Power Test			
Number of Questions	Bad	Enough	Good
16	3	10	3

Based on the results of the calculation of the level of difficulty of the 16 questions, there were 9 questions in the easy category, 6 questions in the moderate category, and 1 question in the difficult category. The results of the discrimination test obtained 3 questions in the poor category, 10 questions in the sufficient category, and 3 questions in the good category. A virtual laboratory is a set of laboratory equipment consisting of interactive multimedia-based software that can be operated via a computer and gives users the impression that they are in a real laboratory (Zine et al., 2019; Prasetya et al., 2023). Virtual laboratories allow students to learn with a case study approach, interact with laboratory equipment, conduct experiments, analyze experiments, and evaluate the processes carried out in the laboratory.

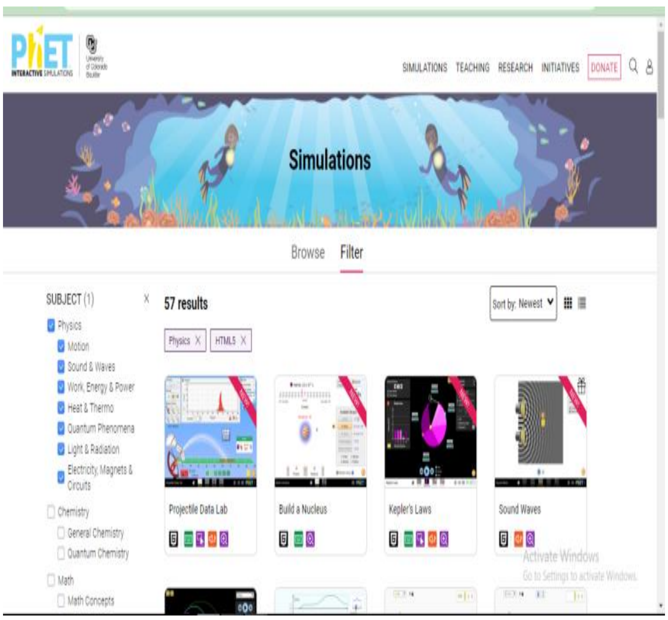

Figure 1. PhET home page view

Figure 2. Go-labs home page view

Through visual displays, animations, and representations adapted from real laboratories, students can see into the devices they operate. So, the possibility of exploring, experimenting, and learning becomes more dynamic with a virtual laboratory (Veza et al., 2022). The use of virtual laboratories in learning models can improve students' understanding of concepts. This is in line with the results of research by Gunawan et al. (2018), who found that the use of virtual laboratories can improve students' understanding of concepts by utilizing tests that have been conducted. The types of virtual laboratories used in this study were PhET (Physics Education Technology) and Go-Lab (Global Online Science Labs).

PhET is a series of interactive simulations that are very beneficial in integrating computer technology into learning or experiments. PhET is an interactive simulation of physical phenomena, based on research that is provided free of charge, such as in physics, chemistry, biology, earth sciences, and mathematics. PhET was developed by the University of Colorado at Boulder, America (University of Colorado at Boulder) in order to provide virtual laboratory-based MIPA teaching and learning simulations that make it easier for teachers and students to learn (Simbolon & Silalahi, 2023). This PhET simulation is designed to help students understand difficult concepts through virtual experiments that allow exploration without risk.

By utilizing this technology in understanding learning contextually, teachers can create interesting learning experiences and provide opportunities for students to develop critical thinking skills (Li, 2023). According to Inayah et al. (2021), each learning media has various advantages both in terms of use and form, as well as PhET simulations which have the advantage of being useful to replace real laboratories so that students can still do practicums without having to use real laboratories, practicums with PhET simulations only need to use a computer that already has the PhET application in it, practicums can be done online or offline. In addition to the benefits in terms of learning, PhET simulations are also very interesting in terms of their use, easy, fun and enjoyable. Using this PhET simulation also avoids accidents during practicums such as those that occur when carried out in real laboratories. The PhET virtual laboratory applied in Physics learning can develop representation skills so that students find it easy to understand concepts and solve problems.

The application of PhET can minimize the occurrence of work accidents that can damage practicum equipment. The learning process with the PhET virtual laboratory makes students' learning activities fun, not boring, and the learning atmosphere becomes relaxed because they are not burdened by difficult Physics concepts. The use of the PhET virtual laboratory actively involves students in learning activities. Students can individually operate experiments virtually, modify values in simulations, and conduct discussions so that students can master physics concepts well. The emergence of increased student learning activities after using this application has an effect on reducing misconceptions (Erna et al., 2021).

Go-Lab is a digital ecosystem that offers various platforms such as virtual laboratories, interactive learning applications, inquiry learning spaces (ILS), and others that can be used as learning support facilities. The initiator of Go-Lab was Mr. Ton de Jong from Europe in 2013. In 2019, golabz had a total of 614 virtual laboratories, 375 of which were physics laboratories. Go-Lab is one of the virtual laboratory pages that presents a digital platform in an inquiry learning package. The development of autoused can facilitate educators who are still beginners in the process of developing their abilities, one of which is digital. The use of go-lab in collaborative learning can stimulate students' curiosity because there are games as well as learning materials for students. In addition, the application of Go-Lab virtual laboratory learning media can improve students' understanding of concepts compared to conventional learning (Simbolon et al., 2023).

The analysis of research data in the cognitive domain consists of pretest and posttest scores. The pretest results of students in the experimental class with an average score of 54.64, in the control class the average score was 46.43. While the average posttest score of students in the experimental class was 76.78, in the control class the score was 64.28. This is supported by research by Hermansyah et al. (2019), which states that virtual laboratories in inquiry learning can improve students' mastery of physics concepts. Mashami et al. (2023) also stated that there is an effect of implementing virtual laboratory simulations on students' understanding of concepts. Likewise Yang et al. (2024) stated that the use of an approach that combines practice and virtual has an effect on students' practical skills and abilities. A comparison of the average pretest and posttest scores of the experimental and control classes can be seen in Figure 3.

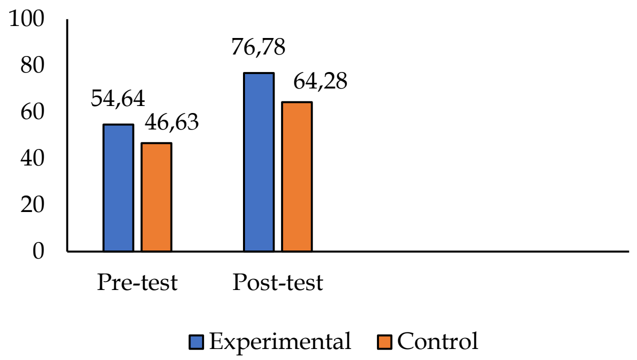

Figure 3. Comparison of average values of concept understanding

The prerequisite test will be conducted first before the hypothesis test is conducted, while the results of the prerequisite test conducted include a homogeneity test which aims to determine the variance of the initial abilities of students in the experimental class and the control class before being tested and given treatment, and a normality test aims to determine whether the final test data on the conceptual understanding ability of the two classes is normally distributed or not. In Table 3, it is found that the F_(count) value is smaller than the F_(table), which is 0.43 ≤ 0.52 at a significance level of 5%. Meanwhile, the normality test found that 〖χ^2〗 _count < 〖χ^2〗 _table. From this information, it can be concluded that both samples are homogeneous and normally distributed.

Table 3. Results of the Homogeneity and Normality Tests of the Pretest

	Experimental Class	Control Class
Number of Students	28	28
Average	54.64	46.43
Standard Deviation	15.30	9.98
Variance	299.87	127.51
f(count)		0.43
f(table)		0.52
〖χ^2〗 _count	6.36	3.07
〖χ^2〗 _table		7.81
Category		Homogen Normal

In Table 4, it is found that the F_(count) value is smaller than the F_(table), which is 1.02 <1.90 at a significance level of 5%. Meanwhile, for the normality test, it was found that 〖χ^2〗 _count is smaller than 〖χ^2〗 _table. From this information, it can be concluded that both samples are homogeneous and normally distributed. The N-gain test is the difference between the pretest and posttest values, gain indicates an increase in students' understanding of the concept after learning is carried out.

Table 4. Results of the Posttest Homogeneity and Normality Tests

	Experimental Class	Control Class
Number of Students	28	28
Average	76.78	64.28
Standard Deviation	11.80	11.89
Variance	178.17	180.95
$F_{(count)}$		1.02
$F_{(table)}$		1.90
〖χ^2〗 _count	7.29	0.45
〖χ^2〗 _table		7.81
Category		Homogen Normal

Table 5. N-gain Test Results

N-gain value	Experimental Class	Control Class	Category
g ≥ 0.70	11	5	High
0.7 > g ≥ 0.30	14	11	Medium
g ≥ 0.30	3	12	Low
Amount	28	28	

Based on Table 5, the N-gain values are categorized as high, medium, and low. In the high category, the experimental class has 12 students and the control class has 5 students. The medium category in the experimental class has 14 students and in the control class there are 11 students. For the low category in the experimental class there are 3 students and in the control class there are 12 students. Meanwhile, the average N-gain value in the experimental class is 0.58 and the average N-gain value in the control class is 0.40. So it can be concluded that the N-gain in the experimental class and the control class are in the medium category. However, in the experimental class, the increase in the ability to understand concepts is more significant than in the control class. Based on the results of the N-gain test calculation and it is known that the data for both classes are normally distributed and homogeneous, so the hypothesis test used is a prerequisite for parametric statistics, the polled variance t-test. The results of the hypothesis test can be seen in Table 6.

Table 6. Hypothesis Test Results

Class	N	Average	Varians	t_{count}	t_{table}
Experiment	28	76.78	178.17		
Control	28	64.28	180.95	3.49	2

Based on Table 6, it can be seen that the t_count value is greater than the t_table, which is 3.49 > 2.00. This is in accordance with the hypothesis testing criteria, namely t_count > t_table, so H_0 is rejected and H_a is accepted. So, it can be concluded that the use of a virtual laboratory using the guided discovery learning model has an effect on the understanding of concepts in static electricity material for class XII students of SMAN 1 Monta in the 2022/2023 academic year. In line with that, based on the results of research conducted by Haryadi et al. (2020), stated that PhET software media makes it easier for students to understand the learning process because students not only hear explanations, but directly conduct their own experiments and can be done repeatedly. PhET simulation media is effectively used to help teachers and students in learning physics concepts. The use of go-lab in collaborative learning can stimulate students' curiosity because there are games as well as learning materials for students. Then, the use of go-lab in collaborative learning with the aim of improving students' critical thinking skills can be applied in physics learning in the classroom, especially for schools that are lacking in terms of procuring practical tools.

Conclusion

Based on the research results and discussions that have been presented, it can be concluded that the use of virtual laboratories in Guided Discovery learning has an impact on students' understanding of the concept of static electricity material.

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Conceptualization, H.; methodology, A. D.; validation, M. T.; formal analysis, H.; investigation, A. D.; resources, M. T.; data curation, H.: writing—original draft preparation, A. D; writing—review and editing, M. T.: visualization, H. All authors have read and agreed to the published version of the manuscript.

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In publishing this article, we declare that there is no conflict of interest.

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