Jurnal Ilmiah Sekolah Dasar
Volume 7, Number 3, 2023 pp. 461-468
P-ISSN: 2579-3276 E-ISSN: 2549-6174
Open Access: https://doi.org/10.23887/jisd.v7i3.61001

Virtual Laboratory-Based Physics Learning "PhET Simulation" to Improve Student Learning Activities

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ARTICLE INFO

Article history:
Received April 30, 2023
Accepted July 30, 2023
Available online August 25, 2023

Kata Kunci:
Aktivitas, Hasil Belajar, Laboratorium Virtual, PhET Simulation

Keywords:
Activity, Learning Outcmes, PhET Simulation, Virtual Laboratory

ABSTRAK

Pesatnya perkembangan teknologi informasi di era digital harus dimanfaatkan secara optimal untuk meningkatkan kualitas pembelajaran Fisika. Penggunaan laboratorium virtual dapat menggantikan laboratorium nyata sebagai sarana untuk membuktikan teori, hukum, dan konsep-konsep fisika. Penelitian ini bertujuan menganalisis penggunaan media virtual berupa PhET *simulation dalam sebagai alternatif pengganti eksperimen nyata* (reel)*. Jenis penelitian ini adalah Quasi Experimen) dengan memberikan perlakuan berupa pembelajaran. Subjek penelitian adalah mahasiswa Universitas Quality yang dibagi menjadi 2 kelas, yaitu kelas eksperimen (2A23) berjumlah 32 orang dan kelas kontrol (2B22) berjumlah 33 orang mahasiswa. Teknik pengumpulan data dilakukan dengan menggunakan instrumen penelitian, yaitu tes hasil belajar dan observasi. Uji hipotesis dalam penelitian ini menggunakan analisis* varians (Anava*) 2 arah* (Two Way Anova) pada General Linear Model *(GLM) univarians dengan program SPSS 21. Dari hasil penelitian, terdapat perbedaan yang signifikan antara hasil belajar IPA Fisika dan tingkat aktivitas mahasiswa pada kelas yang diajar dengan menggunakan laboratorium virtual berbasis simulasi* PhET *dibandingkan kelas yang diajar dengan metode konvensional, sehingga terdapat dinteraksi yang signifikan antara metode pembelajaran dan tingkat aktivitas terhadap hasil belajar IPA Fisika mahasiswa. Disimpulkan penggunaan metode pembelajaran* virtual laboratory *berbasis* PhET simulation *khususnya pada materi fluida berpengaruh terhadap hasil belajar mahasiswa.*

ABSTRACT

The rapid development of information technology in the digital era must be utilized optimally to improve the quality of learning Physics. The use of virtual laboratories can replace real laboratories as a means of proving theories, laws, and concepts of physics. This study aims to analyze the use of virtual media in the form of PhET simulation as an alternative to real experiments (reels). This type of research is an experiment) by providing treatment in the form of learning. The research subjects were Quality University students divided into 2 classes, namely the experimental class (2A23), totaling 32 students, and the control class (2B22), consisting of 33 students. Data collection techniques used research instruments, namely learning achievement tests and observations. Hypothesis testing in this study used a 2-way analysis of variance (Two Way Anova) on the univariance General Linear Model (GLM) with the SPSS 21 program. From the results of the study, there was a significant difference between the learning outcomes of Science Physics and the level of student activity in class compared to classes taught using a conventional method, so there is a significant interaction between learning methods and activity levels on student learning outcomes in Science Physics. It was concluded that using virtual laboratory learning methods based on PhET simulation, especially on fluid material, affected student learning outcomes.

1. INTRODUCTION

Education in a school does not only aim to provide subject matter, but emphasizes how to invite students to discover and build their own knowledge so that students can develop life skills and be ready to solve problems faced in life (Andrianto & Suyitno, 2021; Hermino & Arifin, 2020). Education does not only aim to provide subject matter, but emphasizes how to invite students to discover and build their own

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knowledge so that students can develop life skills and be ready to solve problems faced in life. Education is not something static but something dynamic that demands continuous improvement (Kateryna et al., 2020; Kim et al., 2019).

Until now, science lessons, especially physics, still lack a place in the hearts of students. Physics is considered a difficult and less fun subject. Teachers also do various ways to overcome it so that physics subjects are more fun and enjoyable, so that they are motivated to learn physics (Anggraeni & Sole, 2018; Astalini, Kurniawan, et al., 2019). One of the important problems in learning physics is the low quality of learning at various levels of education. The quality of physics learning processes and outcomes is determined by many factors, one of which is the availability of laboratory facilities in schools. Laboratory activities or experiments are important things to do in learning physics because through experimentation aspects of the product, process, and attitudes of students can develop (Stern et al., 2017; Williams, U. J., & Dries, 2022). Physics is a compulsory subject for the Science major at the senior high school education unit level. Physics is also a science subject that is closely related to scientific concepts (Apriyanti et al., 2020; Gunawan et al., 2019). Physics learning has the goal of forming students' reasoning abilities, namely the formation of logical, systematic thinking abilities, and having objective, honest, and disciplined characteristics in solving or solving a problem (Festiyed et al., 2019; Saidin et al., 2015).

Doing experiment in the laboratory is an important educational component to allow students to gain experience. Practicum is part of teaching which aims to give students the opportunity to test and implement in real situations, what is obtained from theory and practical lessons (Astalini, Darmaji, et al., 2019; la Velle et al., 2020). To realize the experimental process in the laboratory, educators must pay attention to the availability of space, materials and equipment. Many researchers in science education recognize that laboratory research increases students' interest and abilities for science subjects.

As an alternative so that meaningful learning through practicum is carried out is by carrying out virtual practicum activities. Virtual practical activities are practicums with laboratories in digital form on computers as state in previous study (Firdaus et al., 2022). Practicum using a virtual laboratory is an experiment without an actual (real) laboratory that encourages students to link theoretical and practical aspects. There are several reasons for doing practicum with a virtual laboratory, including that practicum is difficult to do in a real laboratory, or because there are no or minimal practicum tools (Gunawan et al., 2018; Kua et al., 2021). By using a virtual laboratory, students can do practicum whenever and wherever they want, so they can test concepts that have been received through practicum in a virtual laboratory until they understand the concept (Falode & Gambari, 2017; Gunawan et al., 2019). With the existence of a virtual laboratory, students are free to independently or in groups to do practicum without fear of breaking or running out of equipment. Practicum can also be carried out even though the equipment in the physical laboratory is not available and there is no reason for the teacher not to carry out practicum activities, it can even be an alternative for schools that do not have laboratory facilities, so that students' scientific work competence can be achieved.

Research on the use of Physics Education Technology (PhET) simulation in physics learning has been carried out a lot. Like the research that has been done by that learning physics using PHET simulation attracts more students' interest and attention have implemented PhET simulations to increase students' understanding and motivation in studying the solar system (T. da. N. Abdjul & E, 2019; Arifin et al., 2022; Nailufar & S., 2022). Other research has also been carried out to analyze student learning activities and outcomes when studying effort and energy (Panda & B.Y., 2021), sound using Physics Education Technology (PhET) as a virtual laboratory (T. Abdjul & Ntobuo, 2018). The simulations provided by PhET are very interactive and easy to use so that students are interested in learning by exploring directly and can experiment in a relatively short time. PhET simulation can also provide a more concrete learning experience through a simulation of a form of experience that approaches the real situation and takes place in an atmosphere without risk. The aim of this study is to analyze the use of virtual media in the form of PhET simulation as an alternative to real experiments (reels).

2. METHOD

This research is a quasi-experimental research (Quasi Experiment) by giving treatment in the form of learning (Madadizadeh, 2022; Rogers & Revesz, 2019). In this study, there were two research classes with different treatments, namely the experimental class and the control class. The experimental class was given virtual laboratory-based learning in the Physics Science Learning course, while the control class used conventional learning. This research was conducted at the University of Quality Medan with the population in this study being all students at the University of Quality Medan. The sample was divided into 2 classes, namely the experimental class (2A23) with 32 students and the control class (2B22) with 33 students. Sampling technique The sampling technique in this study used the Cluster Random Sampling technique. The research design used is experimental research with the consideration that this research seeks to determine the influence and relationship between a variable on other variables. Research design is show in Table 1.

Table 1. Research Design

Group	Pretes	Treatment	Posttes
Experiment Class	X_1	P_1	X_2
Control Class	Y_1	P_2	Y_2

The research design can be presented with a 2x2 factorial design with a 2-way analysis of variance (Anova) technique as presented in Table 2.

Table 2. Research Activiy Design

Parameter	Experiment Class (A_2)	Control Class (A_2)
High Activity (B_1)	B_1A_2	B_1A_2
Low Activity (B_2)	B_2A_2	B_2A_2

In this study, the moderator independent variable was the level of student physics learning activity. The level of student activity includes all activities carried out both physically and spiritually that lead to the learning process such as asking questions, submitting opinions, doing assignments, being able to answer student questions, lecturers, working together between students and being responsible for the assignments given. The dependent variable in this study is student learning outcomes in physics lessons, namely the results of cognitive achievement of students in the cognitive domain of Bloom's Taxonomy. Data collection techniques were carried out using research instruments, namely learning achievement tests and observation of activity levels in the Science Learning Physics course.

Hypothesis testing in this study used 2-way analysis of variance (Two Way Anova) on the univariance General Linear Model (GLM) with the SPSS 21 program. In this hypothesis test the significance level (α) was set = 0.05. The significance level is a number that indicates how big the chance of an analysis error is. The statistical hypothesis that needs to be tested in this study is Reject Ho, if FA > $F_{table(dbA;dbB;0.05)}$, in other cases accept Ho.

3. RESULT AND DISCUSSION

Result

The data described in this study include data on learning outcomes and data on student learning activities in the Science Learning Physics course. Student learning outcomes consist of 2 groups, namely groups of students who are taught based on virtual laboratories and groups of students who are taught using conventional learning. Learning activity is one of the factors that can influence the success of learning activities as measured by using observation during the learning process. Based on the research data in the form of learning outcomes of Natural Science Learning Physics obtained from the data of the average pre-test, post-test student learning outcomes and normalized gain for the experimental and control classes are presented in Table 3. Average value of pretest and posttest for science learning physics courses is show in Figure 1.

Table 3. Data on the Average Value of the Pretest, Posttest and Gain of Physics Learning Outcomes

Group	Pretes	Posttes	Gain
Experiment Class	45.38	87.16	0.77
Control Class	58.12	74.18	0.35

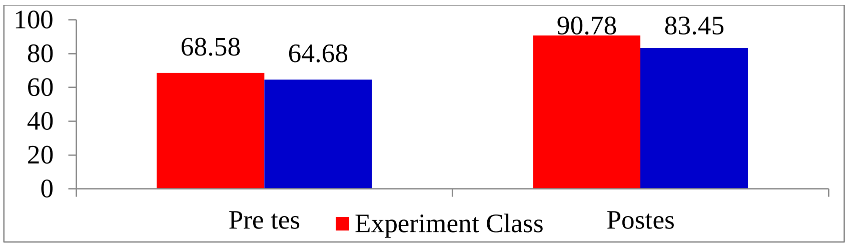


Figure 1. Average Value of Pretest and Posttest for Science Learning Physics Courses

Figure 1 shows that the experimental class showed higher average pretest and posttest scores compared to the control class. The average pretest scores for the experimental and control classes were 58.12 and 45.38. While the average post-test scores for the experimental and control classes were 87.16 and 74.18. After calculating the average pretest and posttest values, then the normalized gain values for each class are measured. Table 4 shows that the average normalized gain value in the experimental class (0.77) is higher than the control class (0.35).

Table 4. Interpretation of the Average Value of Normalized Gain

Group	Gain	Category
Experiment Class	0.77	High
Control Class	0.35	Medium

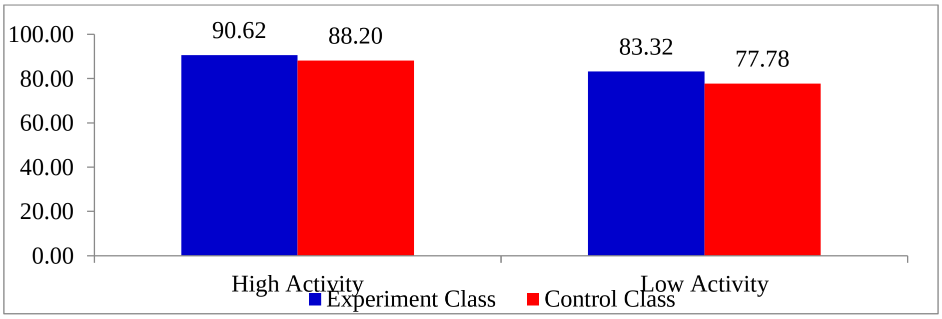
Table 4 it is explained that the average student gain value in the experimental class shows high criteria, while the control class shows medium criteria. Based on the results of the analysis of the gain value, it can be explained that each class has an increase in student learning outcomes in Science Physics. However, the experimental class, namely a class that uses a virtual laboratory based on PhET simulation, has a higher improvement compared to a class taught using conventional learning.

Data Description Value of Student Learning Activities

Based on research data in the form of students' Science Physics learning activities obtained through observing learning activities during teaching and learning activities which are summarized in Table 5.

Table 5. Data of Average Value High and Low Activity Levels

Group	High Activity	Low Activity
Experiment Class	90.62	83.32
Control Class	88.20	77.78



Figures 2. Data of Average Value High and Low Activity Levels

Base on Figure 2, high activity level in the experimental class showed an average of 90.62 while in the control class it was 88.20. While the average value of the low activity level of the experimental class was 83.32 while the control class was 77.78. So it can be concluded from these data that the average value of the experimental class is higher than the control class.

Research Hypothesis Testing

To test the research hypothesis, the Unvariate General Linear Model (GLM) was used using the SPSS version 22 program at a significance level of $\alpha = 0.05$. The sample group whose activity level was measured was first sorted from high to low activity level to classify students in the high and low activity level categories. Where the level of student learning activity is determined based on the average value and standard deviation of each class. Descriptively based on the 2-way Anava statistics with the Unvariate General Linear Model (GLM), the average results of learning Science Physics in the two classes are obtained, which are presented in Table 6.

Based on Table 6, it was obtained that the average value of student learning outcomes in Science and Physics at a low activity level in the control (conventional) class was 71.28 while at a high activity level it was 77.67. the total average learning outcomes of Science Physics students who have low and high activity levels is 74.18. The average value of students' Science Physics learning outcomes at low activity levels in the experimental class (virtual media lab) was 88.21 while at high activity levels it was 85.62. the total average learning outcomes of Science Physics students who have low and high activity levels is 88.21. The average value of the overall science learning outcomes for students who have a low activity level is 79.97, while those who have a high activity level are 81.36. Calculation of physics learning outcomes using two way anova is show in Table 7.

Table 6. Statistical Distribution of Physics Learning Outcomes

Descriptive Statistics				
Category	**Activity**	**Mean**	**Std. Deviation**	**N**
Experiment Class	High	88.21	6.97	13
	Low	85.62	7.63	19
	Total	87.16	7.37	32
Control Class	High	77.67	10.32	15
	Low	71.28	7.69	18
	Total	74.18	9.40	33
Total	**High**	**81.36**	**9.65**	**28**
	Low	**79.97**	**11.43**	**37**
	Total	**80.57**	**10.64**	**65**

Tabel 7. Calculation of Physics Learning Outcomes Using Two Way Anova

Source	**Type Iii Sum Of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	3120.76[a]	3	1040.25	15.37	.000
Intercept	413781.85	1	413781.85	6112.76	.000
Model	2458.87	1	2458.87	36.33	.000
Aktivitas	598.777	1	598.777	6.670	.012
Model * Aktivitas	320.57	1	320.57	4.736	.033
Error	4129.18	61	67.69		
Total	**429191.000**	**65**			
Corrected Total	**7249.94**	**64**			

Based on Table 7, it can be seen that the learning model applied has a significant influence on student learning outcomes as indicated by a significance price of 0.000 <0.05. There are significant differences in learning outcomes between students who are taught on a virtual laboratory basis using PhET simulations and conventional learning. Based on the level of student learning activity also has a significant influence on learning outcomes, which is indicated by the significance price of 0.012 <0.05. to see the interaction of learning methods with learning activities on student learning outcomes in Science Physics students used the Two Way Anova test with Univariate GLM. Based on Table 7 the significance price (sig) (Model*Activity) is 0.033. Because of the sig. 0.033 <0.05, in this case Ha is accepted, which means that there is a significant interaction between virtual laboratory-based learning methods using PhET simulation and conventional methods with activity levels on student learning outcomes in Science Physics. Interaction between learning methods and activity levels on student science physics learning outcomes is show in Figure 3.

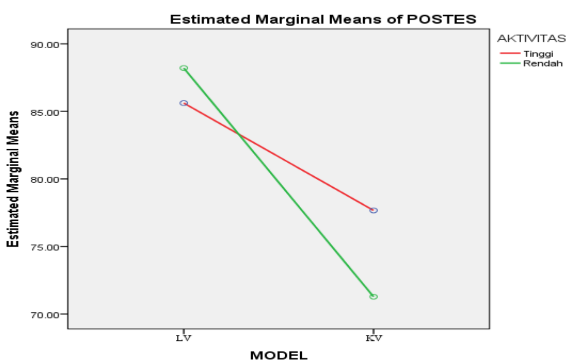


Figure 3. Interaction Between Learning Methods and Activity Levels on Student Science Physics Learning Outcomes

Discussion

Learning Science Physics based on PhET simulation is one of the efforts made by teachers/lecturers to make learning Science Physics more fun both online and offline. So that students do not feel bored, depressed or bored with learning. Virtual laboratories using PhET simulation provide opportunities for students to conduct experiments in a more fun way (Arifudin, 2021; Ramadani & Nana, 2020). This is because PhET simulation has an attractive appearance. PhET simulation provides an animated, interactive, and game-like setting that allows scientists to conduct experiments. The existence of animation is able to depict abstract concepts into real ones (Agustini et al., 2020; Sastradika et al., 2021). Such an animation of the current traveling in an electric circuit can be seen clearly through the PhET simulation. Students are also given the freedom to explore the application. So that students' skills, understanding and knowledge will develop.

The use of a virtual laboratory can visualize an abstract symptom or a complex experiment that is commonly experienced when carrying out real experiments in the laboratory, so that it can increase the learning activities of students to solve the problems they face (Sukerti & Susana, 2019; Zamora-Antuñano et al., 2022). The simulation emphasizes the correspondence between real phenomena and computer manipulation and is then presented in the form of a physical conceptual model that is easy for students to understand (Ade-Ojo et al., 2022; Akuma & Callaghan, 2019; Siti et al., 2021). In addition, experimenting using a virtual laboratory can support laboratory practicum activities that are interactive, dynamic, animative, and in a virtual environment so that they are not boring so that they support cognitive (minds-on), affective and psychomotor development (Fatimah & K.C., 2022; Nirmala & Darmawati, 2021). Through a PhET simulation-based virtual laboratory, it makes the learning process easier and more fun to see, read, digest, remember, because the concepts of the material being taught are more concrete and easy to understand, then it makes it easier for teachers to convey a lot of material in one place so that time is used more efficiently, so as to increase students' understanding of concepts and further encourage students to achieve success (Agustina & Dwikoranto, 2021; Sulistiawati & Prastowo, 2021).

As a suggestion to support the achievement of learning in the classroom, teachers and lecturers are expected to be able to make students' and students' experiences in learning more, especially in terms of practice. If real laboratories are inadequate, teachers and lecturers create alternative experiments through virtual laboratory facilities, so that students and students can explore their theoretical knowledge into practice. Teachers should also have the ability and knowledge to design learning in a more interesting and easy-to-understand way so that it can be used as an aid in transferring subject matter to students and students. Virtual laboratories can be applied to subjects that require practicum to provide a clearer picture of the practicum results.

4. CONCLUSION

Based on the results of the research conducted, it can be concluded that the use of virtual laboratories can provide solutions in terms of overcoming the limitations of laboratory facilities and infrastructure by using virtual media in the form of PhET simulations as an alternative to real experiments (reels) as evidenced by increased learning outcomes and student activities in class. In addition, there is a significant difference between science physics learning outcomes and student activity levels in classes taught using a PhET simulation-based virtual laboratory compared to classes taught using conventional methods, so there is significant interaction between learning methods and activity levels on science physics learning outcomes. student. This means that the use of virtual laboratory learning methods based on PhET simulation, especially on fluid material, has an effect on student learning outcomes.

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