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The Effect of PhET Virtual Laboratory Implementation on Students' Higher Order Thinking Skills

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Abstract: This study aimed to know the effect of using PhET virtual laboratory towards students' higher order thinking skills on linear motion. This research is quasy experimental research that uses the static group pretest-posttest design. The population of this research is all grade VIII students of MTsN mbon in the academic year 2021/2022 and the sample of this research is grade $VIII_4$ as experimental group and $VIII_5$ as control group that determined by simple random sampling technique. The instrument that used to collect the data is test HOTs that made in terms of multiple choices test. The data is analyzed by statistical formula of N-gain and t-test by SPSS 26. The result of N-gain of experimental group HOTs is 0.40 and control group is 0.19. The result of t-test shows that t_{count} of HOTs is 7.762 ≥ t_{table} is 2.000. It means that there is a significant difference of HOTs of students on the linear motion. Therefore, it can be concluded that the use of virtual laboratorial PhET has positive effect towards high order thinking skill of students on the linear motion.

Keywords: Higher order thinking skills; Linear motion; PhET simulation; Virtual laboratory

Introduction

Natural Sciences is a science that studies natural phenomena, which occur regularly and systematically. Based on the 2013 curriculum, one of the objectives of learning science in junior high school is to develop the ability to think, behave, and act scientifically. Students are not only expected to master science concepts theoretically, but they are also expected to be able to prove science concepts from science theory obtained using scientific methods in learning science at school. Through science learning, students can explore independently or be guided to find answers from their curiosity about various natural events that occur. Therefore, science learning is always closely related to the scientific process.

The implementation of the 2013 curriculum was developed as a support to face future demands that open up increasingly fierce competition in life and directly impact the demands of increased human resources. Learning activities through a scientific approach should develop students' thinking skills. 21st-century education needs thinking skills, one of which is higher-order thinking skills. This skill trains students in reasoning and solving more complicated problems, so students have broad insight and are able to think to keep it up to date with today's conditions.

Higher-order thinking skills in science learning are a higher way of thinking than just memorizing science facts and concepts and how to use the mind broadly to solve new or more complicated problems (Ariyana et al., 2018). Therefore, in order to develop these skills, every student must be involved in a meaningful learning process in learning science at schools. Meaningful science learning is not only conducted face-to-face in the classroom. Science learning is also cannot be separated from practical activities.

In early 2020, science laboratory practicum activities at schools did not go as expected. The government implemented learning from home program during the COVID-19 pandemic. Teachers and students no longer meet directly in carrying out learning, especially practicum activities in laboratories at school. The science curriculum in junior high school has several basic competencies that emphasize laboratory activities. Thus, students' abilities in science learning will be comprehensive if theory and practice can work.

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Based on a preliminary study at one of the junior high schools in Ambon City, it was found that there had been no science laboratory practicum activities since the COVID-19 pandemic. The absence of this practicum activity causes students' science test results not to meet the Minimum Mastery Criteria. The students are less skilled in conducting scientific observations and investigations. Science learning is carried out online with the lecture method. This learning is carried out less interactively, so the students get bored quickly because the learning is only done in theory without practice.

Furthermore, the teacher also sometimes provides presentation materials for students to read independently. Thus, most students are still unable to relate the science concepts they have learned to the problems given, and they also have difficulties determining the mathematical equations used. Students are in very much need of science laboratory practicum activities because they can make direct observations and help them train higher-order thinking skills through a practicum (Andrian & Rusman, 2019).

Virtual laboratories in science learning can be alternative laboratories to be used to implement practical activities. This virtual laboratory gives students the freedom to carry out practical activities anytime and anywhere without being guided directly by the teacher (Muzana et al., 2021). A virtual laboratory is a computer-based learning media that contains simulation activities in the science laboratory. Virtual laboratories present simulations of real labs as a student-centered approach. Students are presented with an object as a virtual representation of a real object used in a real laboratory (Faour & Ayoubi, 2018).

PhET (Physics and Education Technology) virtual laboratory is an interactive science media with the help of a computer application that contains simulations of science experiments. One of the advantages of a virtual laboratory is that it can be operated anytime and anywhere, does not require tools or chemicals, and through this laboratory, students can observe molecular aspects, such as interactions between particles, movement of particles, changes in the temperature of a substance due to environmental factors, and reading data in the form of numbers and their changes can be observed directly (Setiadi & Muflika, 2012).

Science learning associated science concepts with phenomena that occur in daily life. One of the science materials that is closely related to students' daily lives is linear motion. Linear motion material is one of the materials in science learning that has many abstract concepts. Thus, in order to observe directly and prove the theory of the material, it can be carried out through the PhET virtual laboratory practicum.

Most previous research has studied the PhET virtual laboratory. Virtual laboratories significantly influence students' achievement and learning outcomes (Bajpai & Kumar, 2015; Hermansyah et al., 2015; Putri, Hamid & Yusrizal, 2016; Subiki et al., 2022; Tüysüz, 2010; Wuryaningsih, 2014). Virtual laboratories can improve students' conceptual understanding of chemistry learning (Hikmah et al., 2017; Jagodzinski & Wolski, 2014; Sumargo & Yuanita, 2014). Implementing a virtual laboratory with previous PhET simulations has improved student achievement, learning outcomes, and conceptual understanding. However, no research has studied its effect on students' higher-order thinking skills (C4 – C6).

Based on this view, the objective of this study is to determine the effect of increased PhET virtual laboratory on the higher-order thinking skills of 8th-grade junior high school students in linear-motion material.

Method

This study is quantitative with quasi-experimental research (quasi-experiment). The quasi-experimental research can provide information that predicts the information that can be obtained through actual experiments under conditions where it is not possible to control all relevant variables. This study consisted of two classes: the experimental class (the class that received treatment in the form of PhET virtual laboratory learning) and the control class. The two classes were given different treatments and were given pretest and posttest. Thus, the design used was the static group pretest-posttest research design (Fraenkel & Wallen, 2007).

The subjects in this study involved the population of all 8th-grade students for the 2021/2022 academic year at the Ambon State Islamic Junior High School. The population consisted of 11 classes (416 students). Sample determination in this study was selected using a simple random sampling technique because the population is homogeneous. The population is homogeneous, which can be seen from the absence of a favorite class or excellent class labels for each grade in the school. The distribution of students is carried out randomly regardless of the strata in the population. Two classes were obtained from the sample determination: class VIII-4 as the experimental class and class VIII-5 as the control class. Each class consisted of 38 students.

Table 1. Research Design

Pretest	Treatment	Posttest
O_1	X_a	O_2
O_1	X_b	O_2

Description:
O_1 = Pretest
O_2 = Posttest
X_a = Experimental class
X_b = Control class

Data collection techniques include HOTs tests. The HOTs test instrument for students in this study used science learning questions, especially the material for the linear motion for 8th grade, which consisted of Uniform Motion and Uniformly Accelerated Motion. The test was in the form of twenty multiple-choice questions with indicators of HOTs for linear motion questions material, which consisted of (1) diagramming the change in position into a graph of changes in velocity with time, (2) comparing the acceleration of the object's motion based on the table of observations, analyzing acceleration and deceleration based on graphs in velocity with respect to time (v – t), (3) analyzing the object's motion based on the graph of velocity with respect to time (v – t), (4) drawing conclusions from Uniform Motion and Uniformly Accelerated Motion based on distance and time in a linear motion, (5) drawing conclusions from Uniformly Accelerated Motion based on the velocity and acceleration in a linear motion, (6) evaluating the application of Newton's third law of motion in everyday life, (7) predicting linear motion events based on v – t graphs presented, (8) making decisions based on the results of observational data regarding linear motion and (9) categorizing various events that occur in daily life into the type of linear motion.

The students' HOTs test data is a selected response type of test: multiple choices with correct answers (score 1) and incorrect answers (score 0). The score is then calculated and then converted into a mark. The HOTs marks obtained by each student were then analyzed by calculating the gain score normalized by the equation (Hake, 1998).

$$N - gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \quad (1)$$

The normalized gain score is then tested for the prerequisite tests: normality and homogeneity to determine the distribution of scores using SPSS Statistics 26 software. The next step is to test the hypothesis, including a one-way t-test using SPSS Statistics 26 with a significance level of 5% in this test. The decision of this test is with the criteria if Sig.<0.05, then H0 is rejected, and H1 is accepted.

Table 2. Category Level of N-gain

Limitation	Category
<g> > 0.7	High
0.3 ≤ <g> ≤ 0.7	Medium
<g> < 0.3	Low

Result and Discussion

The research results are presented in two statistical analysis results: descriptive and inferential.

Descriptive Analysis Results of Students' HOTs

Descriptive statistics comparison data between the experimental class and the control class can be seen in figure 1.

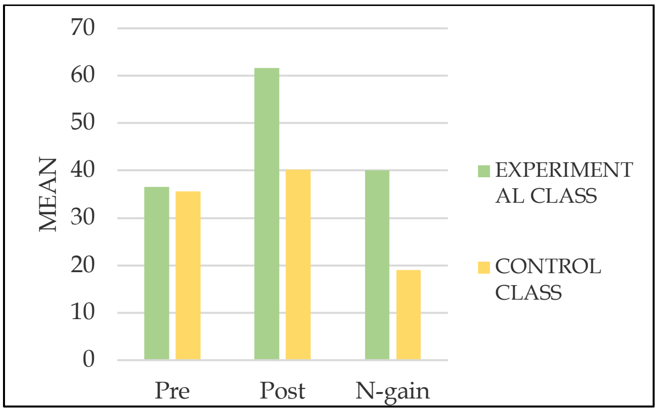

Figure 1. The Mean of Pretest, Posttest, <g> HOTs of Experimental and Control Class Students

In figure 1, it can be seen the pretest scores of the two classes, experimental and control, have a slight difference in the average score of 1.00. This shows the initial ability of students before the treatment is given in the form of applying the same PhET virtual laboratory. In the posttest scores, it can be seen that the average score of the experimental class is higher than the control class, with a difference of 21.32. For the magnitude of the increase or N-gain, it is seen that the experimental class has a higher N-gain of 0.40 (medium category) compared to the control class of 0.19 (low category).

Normality Test Result

In this study, the normality test of the students' HOTs posttest data was analyzed using the SPSS version 26 software program. The test formula used was the Shapiro-Wilk test because the number of samples in this study was small (<100 students). The results of the Shapiro-Wilk test with a value of Sig., which is greater than the significance level (α = 0.05), indicate that the data of the two classes tested is normally distributed.

Table 3. Analysis Results of HOTs Normality Test

Class	Shapiro-Wilk Test			Conclusion
	Statistic	Df	Sig.	
Experimental	0.945	38	0.269	Normal
Control	0.959	38	0.178	Normal

Homogeneity Test Results

In this study, the homogeneity test of students' HOTs was analyzed using the SPSS version 26 software program. The test formula used was the Levene Test. The results of the Levene Test with the value of Sig., which is greater than the degree of significance (α = 0.05), indicate that the two data have the same variance or are homogeneous.

Table 4. Analysis Results of HOTs Homogeneity Test (Levene Test)

Levene Statistic	df1 : 1	df2 : 74
Sig.	A	Intepretation
0.08	0.05	Homogeneous

Based on the results of the homogeneity test in Table 4, it can be seen that the data in both classes: experiment and control, with a total sample of 76 students and a confidence level of 0.95, obtained the Sig. value of = 0.08, which is greater than α = 0.05. This means that the two data have homogeneous variance.

Hypothesis Test Result

The results of the normality and homogeneity tests carried out previously showed that the data were normally distributed and homogeneous. Thus, the type of statistic for the average difference test used was a one-party t-test. One-party t-test was carried out using the SPSS version 26 software program.

Table 5. The Analysis Results of the One-party t-test Posttest of HOTs

Parameter	Posttest	
	Experimental Class	Control Class
The Number of Samples	38	38
Mean	61.58	40.26
Standard Deviation	10.01	13.65
Significance		0.000
T_{count}		7.762

Based on the test results, the significance value of the one-party t-test results is 0.000, which is smaller than the significance level of (α = 0.05). This shows that H0 is rejected and H1 is accepted. In addition to the significance value from the calculation results, the t_{count} value is 7.762, which means it is greater than the t_{table} value (2.000). This indicates that it's the same that H_0 is rejected and H_1 is accepted. Thus, at the significance level of (α = 0.05), there is a significant difference in HOTs between students who are taught using the PhET virtual laboratory and students who are taught without using the PhET virtual laboratory.

The N-gain calculation results from both classes' pretest and posttest scores found that the experiment class had an N-gain of 0.40 (moderate improvement category). Meanwhile, the control class is 0.19 (low improvement category). Hence, students who are taught using the PhET virtual laboratory in science learning have better HOTs than students who are taught without using PhET virtual laboratory. This is because students are more active in the learning process to develop their thinking skills to find the answers from the investigation process through virtual practicum activities using PhET on linear motion material. In this learning, the teacher continues to provide material to students online and guides them to solve the problems through the investigation process in the laboratory. Students conduct a series of linear motion experiments, including Uniform Motion and Uniformly Accelerated Motion, guided by student worksheets in their implementation. The implementation of the practicum is carried out online through the PhET virtual laboratory. Students have independence in carrying out the practicum. Through this laboratory, students are free to access it at any time, are flexible, can be conducted repeatedly until they really understand.

The PhET virtual laboratory is a computational medium that includes animations for science learning that are displayed on the website. PhET contains subfiles that can be used independently, as well as the animation that wanted to be shown (Perkins et al., 2006). This application displays abstract mathematical and natural science concepts, and certain materials can be easily explained through this application, allowing students to grasp the concepts being studied more easily (Purwanto et al., 2016). The following is a PhET simulation website display on straight motion teaching materials.

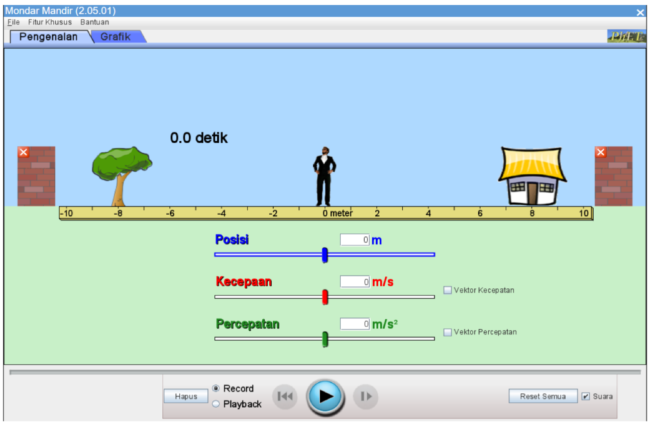

Figure 2. Straight Motion Material in PhET Simulation

The simulation of teaching materials on PhET simulation media has interactive features such as displaying static images, animations, videos, and simulations to keep students interested during the learning process (Rizaldi et al., 2020). In line with this statement, previous research stated that PhET provides images, animations, and interactive simulations that are made like games Thohari et al. (2019), which have an impact on student activity and enthusiasm in learning Pujiyono et al. (2016) and increase concept understanding. students of physics (Batuyong & Antonio, 2018). Furthermore, the appearance of an interesting PhET simulation also allegedly influenced students' curiosity Mahulae et al. (2017), making it effective in helping students understand abstract concepts (Alatas et al., 2017).


Figure 3. Learning Science using PhET Simulation

In this study, students' higher-order thinking skills improved with implementing the PhET virtual laboratory in science learning. This is because applied learning emphasizes student-centered learning. The teacher facilitates students with PhET simulation and is supported by worksheets containing questions to be solved through virtual laboratory activities using PhET simulations. Therefore, students play an active role in developing their creative thinking skills in learning. Therefore, students are trained to conduct scientific inquiry.

The use of this PhET laboratory can pique students' interest, causing them to ask a variety of questions (Masita et al., 2020). In the learning process, students are expected to participate actively by asking questions, evaluating arguments, making inferences, defining terms, and making decisions, so that by the end of the course, they are familiar with higher-order thinking. Furthermore, students can complete the posttest because they already understand the concepts that must be filled out on the answer sheet. In line with Sunni et al. (2014), PhET learning and simulation media create an interesting learning atmosphere, make students more active, and increase students' motivation to understand science, making them more active, and increasing their motivation to understand science. Based on the preceding description, it can be concluded that the PhET virtual laboratory can improve students' higher-order thinking skills. This is consistent with Gunawan et al., (2015), who stated that students' HOTs experienced an increase after implementing the PBL model learning tools with the help of PhET simulations.

As support of virtual practicum activities, teachers have also prepared worksheets for students. Worksheets become a guide for students in carrying out practical activities. The instructions and stages of virtual practicum activities in the worksheets have been clearly explained. In addition, the worksheets also explain the knowledge and skills are accessed, including higher-order thinking skills (HOTs) in practical activities.

Laboratory inquiry learning using PhET simulations increased students' ability to use scientific concepts to predict and explain scientific concepts, be able to identify questions that can be answered through a scientific investigation process, and be able to select relevant information from the large amount of data used to conclude scientific phenomena (Wolf and Fraser, 2013). According to Slameto (2003), increasing attention in the learning process can guarantee good learning outcomes. Thus, learning can prevent students from laziness and boredom and increase students' attention in learning activities.

Conclusion

Based on the research findings, it can be concluded that the application of a PhET virtual laboratory significantly affects students' higher-order thinking skills in linear motion material, there is a significant difference in enhancing higher-order thinking skills between students learning science using a PhET virtual laboratory (experimental class) and students learning science without using a virtual PhET laboratory (control class). Students who learn to use the PhET virtual laboratory can increase higher-order thinking skills overall and at each cognitive level in linear motion material.

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