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The Use of STEM-Based Virtual Laboratory (PhET) of Newton's Law to Improve Students' Problem Solving Skills

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Abstract *– Problem-solving is one of the skills that must be mastered in the 21st century. The objective of this research is to describe the practicality of using a STEM-based virtual laboratory in distance learning (online) to practice problem-solving skills in the subject of Newton's Law. This study's subjects were three classes totalling 102 students of SMA Negeri 1 Cerme Gresik. Employing an experimental design, this research used observation, questionnaires, and tests (pre-test and post-test) as the data collection methods. To analyse the data, several tests (homogeneity test, normality test, gain test, t-test, and effectiveness) were used. The results showed that the mean score of the pre-test was 54.57 and that of post-test was 81.13. This indicates that the students' learning outcomes have increased by 26.38, with the average size of the gain test classified in the medium criteria, namely 0.58 or 58%. The result of this study contributes to the development of online-based learning strategies during the covid-19 pandemic. In brief, the use of STEM-based Virtual Laboratory (PhET) has significant effects on students' problem-solving skills. STEM-based Virtual Laboratory was quite effective for teaching Newton's Law in the platform of online learning.*

Keywords: *Newton's Law, Problem-solving, STEM, Virtual laboratories (PhET)*

I. INTRODUCTION

Since November 2019, the world has been shocked by the news of the Covid-19 outbreak. The World Health Organization (WHO) announced the truth of the outbreak from Wuhan's Chinese city, which then spread to more cities before being transmitted to nearby countries with death rates and isolation treatment for infected cases. Efforts to prevent the spread of the virus by closing public business activities, including closing schools that have been carried out (Jung et al., 2020).

After a few days of the initial Covid-19 outbreak in Indonesia, to be precise on March 24, 2020, circular letter Number 4 of 2020 was issued by the Indonesian Ministry of Education and Culture, which contained learning policies in the emergency period of the Covid-19 outbreak that temporarily indoor and outdoor activities in the entire zone, especially in the field of education, for the teaching and learning process is still implemented. Still, the learning process this time is done at home through distance learning or online.

Part from the economic sector, the education sector was also heavily affected by the covid-19 outbreak, and UNESCO acknowledged this. Various efforts by the Indonesian government to prevent the spread of the covid-19 outbreak with PSBB, Physical Distancing, Social Distancing, and even the application of Lockdown to urge people to study, work and worship at home. No exception in the teaching and learning process that was previously carried out in school face-to-face changed to learning teaching distance or online so that learning will continue to be carried out correctly. With the application of distance learning as a form of learning challenge in the industrial era 4.0, teachers are required to be able to deliver varied education and digital technology (Simarmata et al., 2020)

Today's use is one of the processes in realizing educational innovation and a 21st-century learning style. Where successful learning from a model or media depends on the student's personality. (Nakayama et al., 2007) revealed that some students have not been able to adapt to distance or online learning from all the aspects of the use of technology in education. This matter is due to the elements of the learning area and the individual characteristics of students.

Laboratory activities are integrity in a learning process. The role of the laboratory is also significant to achieve science learning goals. Physics learning is related to natural phenomena that are scientific in the experiment (Chodijah et al., 2012). One of the 21st-century learning is integrated with technology that can be utilized through software such as PhET. PhET is a scientific procedure developed by the University of Colorado (Prihatiningtyas et al., 2013). PhET simulation refers to the relationship between science and real-life phenomena as the basis for interactive learning and a constructive approach and providing creative learning opportunities (Perkins et al., 2012). Learning using a virtual laboratory has several advantages. One of these advantages is being able to explain abstract concepts that cannot be presented through direct delivery, and virtual laboratories can be a place for experiments that cannot be carried out in conventional laboratories (Ariandi & Haryanto, 2010).

STEM learning can be used to raise everyday problems into knowledge that leads to more meaningful learning. STEM is an alternative science learning that can build a generation capable of facing the 21st century (Permanasari, 2016). STEM learning is directly applied in the real world, a form of contextual problem solving based on problem-solving (Winarni et al., 2016). STEM learning requires students to understand the core concepts of material applied, finding solutions, and solving problems (English, 2016). The STEM learning process is carried out using an active learning method that includes communication, collaboration, problem-solving, leadership, creativity, and others (Dewi et al., 2018). Research conducted by Soros., P argues that the STEM learning method can improve students' problem-solving abilities (Soros et al., 2018). This study applies a STEM-based virtual laboratory (PhET) in the learning process to hone students' ability to solve problems in the concept of Newton's Law.

This research was conducted to determine 1) the practicality of using STEM-based virtual laboratories in distance learning (online), 2) the improvement of problem-solving skills by implementing STEM-based virtual laboratories, 3) students' activities when implementing virtual laboratories in online learning.

II. METHODS

This research was conducted by giving treatment to the subjects to apply a STEM-based virtual laboratory, then looking at the treatment's effect. The design of this study was experimental research with one-group pretest-posttest design. The following is the research design of the one group Pretest-Posttest:

Pretest	➔	Treatment or intervention	➔	Posttest
O_1		X_1		O_2

Figure 1. One-Group Pretest-Posttest Design

Sugiyono, 2012: 108

Information:

X_1 = Treatment in the form of learning with the application of a Virtual Laboratory (PhET) and using the STEM model in the experimental group

O_1 = Giving a test before the application of learning (Pretest)

O_2= Giving a test after the application of STEM-based virtual laboratory (PhET) learning application (Posttest)

This research was conducted at SMA Negeri 1 Cerme Gresik located at Jalan Pasar Cerme Lor No. 176 Ngabetan Kec. Cerme, Gresik Regency. The population of this study was three classes with a total of 107 students.

Data collection methods used were tests (pretest and posttest) and observation. The test method aims to measure students' problem-solving skills, while the observation method seeks to obtain students' attitude data during the application of STEM-based virtual laboratories (PhET) in learning.

This study used three stages of procedures: 1) The preparation stage consisted of literature preparation, research problem formulation, RPP sampling, making worksheets, test and non-test instruments. 2) The implementation stage started by giving a pre-test to determine the student's initial abilities. When learning took place, observers made observations related to assessing students' activity. After the learning process was complete, a post-test was given to measure students' problem-solving abilities. 3) The problem-solving and reporting stage was carried out by processing and analysing data, testing hypotheses, and concluding. The inferential statistical methods were employed to analyse the improvement of students' problem-solving abilities after being applied to the virtual laboratory (PhET). Here are the steps to determine the normality test, t-test, and N-gain:

a. Normality test, using the Liliefors formula, which is in equation 1.

$$L_{count} = |F(Z_i) - S(Z_i)| \text{........(1)}$$

Normally distributed if $L_{count} < L_{table}$

b. Hypothesis testing used paired two-sample test. The t-test formula in equation 2.

$$t_{count} = \frac{\bar{x}-\mu_0}{S/\sqrt{n}} \text{..................(2)}$$

With $\bar{x}$: the value of the pretest mean, μ_0 : the value of the posttest mean, S: the standard deviation of the difference, n: the number of samples

H_0 : student learning outcomes do not improve with the application of STEM-based virtual laboratories (PhET)

H_α : Student learning outcomes improve with the application of STEM-based virtual laboratories (PhET)

c. Calculating N-gain as a data analysis technique. The N-gain calculation used the following formula:

$$n - gain = \frac{posttest\ score = pretest\ score}{maximum\ score - pretest\ score}$$

The criteria for increasing problem-solving ability is based on N-gain. If the n-gain value is > 0.7, then it is in the high category. If the n-gain > 0.7 is in a common type, and if the n-gain is < 0.3, it is in a standard class. (Apriyani et al., 2019).

The hypothesis testing was carried out by measuring the differences in students' problem-solving abilities before and after treatment. It was carried out after the normality and homogeneity tests were done. The non-test instrument data in this study were observations that were used to measure students' activity during the application of a STEM-based virtual laboratory. Data processing was calculated using the following formula:

$$percentage\ (\%) = \frac{F}{N} \times 100$$

With the criteria as shown in the Table 1 as follows

Table 1. The criteria of students activity

Percentage of student activity	Criteria
86 – 100%	Very High
71 – 85%	High
56 – 70%	Moderate
41 – 55%	Low
< 40%	Very Low

III. RESULT AND DISCUSSION

The results obtained from pre-test and post-test data and the results of students' questionnaires on the application of virtual laboratories (PhET) during learning. Before being given the application or treatment, the sample was given a pre-test to know the initial ability. After given treatment, the sample was given a post-test to measure the final result of problem-solving abilities. The pre-test results are described in Table 2 below.

Table 2. Pre-test Data Distribution

Distribution data	X MIA 1	X MIA 2	X MIA 3
Average	53.75	61.14	48.71
Minimum	25.00	40.00	25.00
Maximum	80.00	80.00	65.00
Median	55.00	65.00	50.00
Mode	65.00	70.00	40.00
Stdev	15.74	9.93	11.68

Based on Table 2, the average pre-test score of class X MIA 1 is 53.75, class X MIA 2 is 61.14, class X MIA 3 is 48.71. The pre-test value obtained shows that the pre-test average value is still less than the standard of Minimum Mastery Criteria (KKM) value. The test result was the basis in doing an experiment in applying STEM-based virtual laboratories will be applied (Science, Technology, Engineering, and Mathematics). The three classes were given a post-test after being given treatment, while the results are described in Table 3 below.

Table 3. Post-test Data Distribution

Distribution data	X MIA 1	X MIA 2	X MIA 3
Average	82.92	83.71	76.13
Minimum	65.00	65.00	50.00
Maximum	100.00	100.00	90.00
Median	80.00	85.00	80.00
Mode	80.00	90.00	80.00
Stdev	8.81	8.69	8.14

Based on Table 3, the post-test results show that the final problem-solving ability of class X MIA 1 is 82.92, class X MIA 2 is 83.71, and class X MIA III is 76.13. The data indicated that the students' problem-solving ability after using the STEM-based virtual laboratory (PhET) is higher than before the treatment. The normality test in this study was excel-assisted. The results of the pre-test and post-test normality test are in Table 4 below.

Table 4. Normality Test Results

Shapiro-Wilk Test	Sig.
Pretest	0.137
Posttest	0.167

Table 4 shows that the significance of the pre-test and post-test data is > 0.134 (Kolmogorov Smirnov table value), namely 0.137 and 0.167, respectively. Thus, the results were both normally distributed. The pre-test and post-test data were also tested using a homogeneity test. The following table shows the data on the homogeneity test results:

Table 5. Homogeneity Test Results

	Variable 1	*Variable 2*
Mean	54.7549	81.12745
Variance	185.3354	83.12221
Observations	102	102
Df	101	101
F	0.448496	
P(F<=f) one-tail	3.63E-05	
F Criticalone-tail	0.719726	

Table 4 shows that the sig. F data is Fh (F-count) which is 0.448496, and F Critical one-tail (F-table) is 0.719726. If Fh < Ft, then Ho is accepted. From the table, it can be seen that the value of 0.448496 < 0.719726, so it can be concluded that the pre-test and post-test values are homogeneous and normally distributed. The hypothesis test in this study was the parametric statistical test, using excel through the t-test of the pre-test and post-test data. The result of hypothesis testing is shown in Table 6 below.

Table 6. Hypothesis Test Results

T_{count}	**t_{table} (α = 5%)**	**Testing criteria**	**Information**
21.323	1.984	If $t_{count} > t_{table}$ then H_0 is rejected (H_α is accepted)	$T_{count} > t_{table}$ (21.323 > 1.984) H_0 rejected

Based on Table 6, the hypothesis test results show that the alternative hypothesis (H_α) is accepted. This shows that the application of the STEM-based Virtual Laboratory (PhET) has an effect in improving students' problem-solving skills in the discussion of Newton's Law. This result is in line with (Gunawan et al., 2019) research stated that the use of virtual laboratories (PhET) can increase students' creativity and problem-solving skills. Another similar result found in the research conducted by (Soros et al., 2018) which revealed that the STEM learning method can improve the ability to solve physics problems.

The results of experimental research after being given treatment in applying STEM-based Virtual Laboratories (PhET) showed an increase in students' problem-solving abilities, which can be calculated using the N-Gain formula. The gain test value obtained in this study was 0.58.

The gain value shows that the average research sample has increased and is included in the moderate criteria. Students' activity assessment activities in this study are limited to several indicators: 1) Students' activities when implementing the PhET virtual laboratory; and 2) The improvement of students' problem-solving abilities.

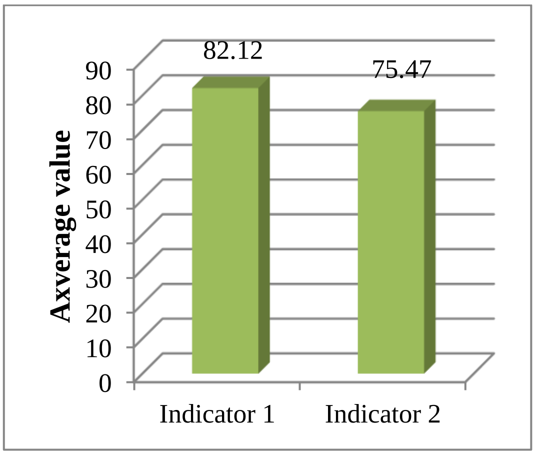

Figure 2. The average value of students' activity

Student activities during learning with the application of STEM-based virtual laboratories (PhET) to practice problem-solving skills are presented in Figure 2. Based on the graph above, the percentage of all students' activities is 82.12%, with good categories in indicator 1 and 75.45% with suitable type in indicator 2.

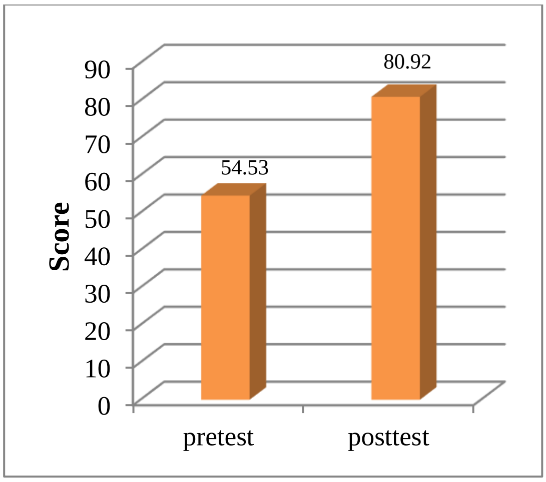

Figure 3. The score of pretest and posttest

The figure 3 above shows that there is an increase in students' learning outcomes which is shown by an increase in the average post-test score of 80.92. This shows that the application of STEM-based virtual laboratories is effective enough to be applied in distance learning (online) to improve students' problem-solving skills.

IV. CONCLUSION AND SUGGESTION

The conclusion of this study is the use of STEM based Virtual Laboratory (PhET) has a significant effect on the students' level of problem-solving skills. There is an increase in students' problem-solving skills. This is proven by the N-Gain value of 0.58 (moderate) and the results of observations of students' activities in learning application of STEM-based virtual laboratories (PhET) which shows average percentage of 78.78% (very good category). The suggestions that the authors propose after conducting this research are (a) STEM learning should be carried out for subject matter that is not a theoretical concept (b) Implementation of STEM learning takes a long time, researchers and teachers must be able to allocate their time so that learning can run effectively.

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