OPEN ACCESS

Jurnal Riset Pendidikan MIPA, 9(1): 31-37, June 2025
ISSN 2549-0192 (e) | 2549-0184 (p)
http://new.jurnal.untad.ac.id/index.php/jrpm/

The Effect of Virtual Experimental Learning on Students' Concept Understanding and Communication Skills on Elasticity and Hooke's Law

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Article History
Received 06 March 2025
Revised 10 April 2025
Accepted 05 Mey 2025

Keywords:
virtual experimental,
concept understanding,
communication skills

Abstract

This study aims to determine the effect of virtual experimental learning on students' understanding of concepts and communication skills. It employed a quantitative quasi-experimental design using a nonequivalent control group design. The population consisted of 257 grade XI MIPA students at SMA Negeri 2 Palu. Samples were selected through purposive sampling, with class XI MIPA 1 serving as the control class and class XI MIPA 2 serving as the experimental class, each consisting of 36 students. The research instruments were five essay questions assessing concept understanding and communication skills. Virtual experimental learning improved students' concept understanding and communication skills by encouraging scientific thinking through experimentation, investigation, observation, and drawing conclusions about scientific concepts and principles, thereby enhancing process skills. Data were analyzed using the N-Gain test to measure improvements in concept understanding and communication skills. The experimental class achieved a medium N-Gain category, whereas the control class remained in the low category. Hypothesis testing employed an independent t test and one-way ANOVA using statistical software at a significance level of 0.05, assuming normally distributed data. The results indicated that virtual experimental learning significantly affected students' understanding of concepts and communication skills on elasticity and Hooke's law, supporting effectiveness.

doi: 10.22487/j25490192.2025.v9.i1.pp.31-37

Introduction

According to Smith et al., (2020) structurally, the aim of developing students' experimental skills is implemented in the laboratory by requiring students to make decisions about the design, analysis, and expansion of experiments. When conducting experiments, learning media are needed as teaching aids. Learning media can be one of the factors that affect the learning process. The use of learning media is adjusted to the development of information and communication technology.

According to (Bunyamin et al., 2021; Saparini et al. (2010)) its application in schools, there are several obstacles that hinder the implementation of practicums such as limited time in the learning process, availability of tools and materials, and a new problem since the Covid-19 pandemic, namely teachers cannot guide students to do practicals directly. Given the importance of the role of practicum in learning, this is the reason that practicum activities must continue to be carried out despite these obstacles, to overcome these problems, an innovation in learning media is needed so that physics experimental activities can still be carried out as they should. One alternative that can be done is to use a virtual laboratory (Safitri, 2011).

The use of virtual laboratories can be designed so that the equipment used is in accordance with the conditions in conventional laboratories. Ahmed & Hasegawa (2014) stated that virtual laboratories make it easier for students to make connections between theoretical and practical aspects. Other researchers also found that the use of computer simulations as virtual laboratories was proven to improve the mastery and understanding of physics concepts and students' creativity (Gunawan et al., 2018). According to Hermansyah et al. (2017) the high achievement of concept mastery is due to the implementation of learning using a virtual laboratory that presents information through the media of text, images, videos, animations, and simulations and is supported by scientific activities to train students in constructing their understanding of concepts physics independently.

Revealed that one of the learning methods that is able to facilitate the achievement of mastery of concepts and student activities as well as students' problem-solving abilities is the experimental method (Simbolon 2015 ; Sulistiawati et al., 2025 ; Putri et al., 2018). The experimental method can provide direct experience for students to carry out scientific and procedural steps.

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In previous studies conducted by Faour & Ayoubi (2018) and Smith et al., (2020) only conducted research related to the use of virtual laboratories on students' mastery of concepts without reviewing students' communication skills. Research (Handayani et al., 2021) shows that distance learning using PhET simulations provides better learning outcomes and can improve students' communication skills. This is also supported by research (Faour & Ayoubi 2018) which shows that the use of virtual laboratory teaching methods has a better effect than interactive demonstrations because the laboratory can visually describe practicum steps and collect practicum data quickly. These studies only discuss students' understanding of concepts, without reviewing the Science Process Skills that students also have. it is necessary to apply Science Process Skills (KPS) in this case students' communication skills.

Based on the description above, the researchers will conduct research on the effect of virtual experimental learning on understanding concepts and students' communication skills on the material of elasticity and Hooke's law. The materials for elasticity and Hooke's law were chosen in this study because the application of elasticity and Hooke's law is very common in everyday life, so this material needs to be applied in virtual experimental learning to identify the extent to which students' understanding of concepts and communication skills on elasticity and Hooke's law. It is hoped that the virtual experimental learning can improve students' understanding of concepts and communication skills.

This paper is intended to determine the effect of virtual experimental learning on students' conceptual understanding and communication skills.

Materials and Method

This research is a quasi-experimental quantitative research. The design used in this study is a non-equivalent control group design. In this design, the experimental class is treated with direct PhET virtual experimental learning as a virtual laboratory where students can directly access the PhET virtual laboratory via https://phet.colorado.edu, while the control class follows the lesson using printout of the PhET display where students only observe the PhET virtual laboratory display on the module. The population of this study were students of class XI MIPA SMA Negeri 2 Palu, totaling 257 students. Sampling using purposive sampling technique. Sampling using purposive sampling technique. From the results of the sample selection, selected classes XI MIPA 1 amounted to 36 and XI MIPA 2 amounted to 36 as samples. this research was conducted during the covid-19 pandemic, this research was conducted online or online using social media for learning activities such as whatsapp, classroom, zoom, and google meet. The instruments used in this research are lesson plans, modules, tests of conceptual understanding and communication skills for materials of elasticity and Hooke's law.were analyzed by descriptive analysis, normality assumption, N-Gain test according to Hake (1999), independent sample t test, and one way ANOVA using statistics software.

Results and Discussion

The research data obtained in this study are the scores of students' understanding of concepts and communication skills on the material of elasticity and Hooke's law class XI SMA Negeri 2 Palu. After analyzing the test of understanding concepts and communication skills, the data obtained from the research results are as in Table 1 and 2.

Table 1. Descriptive Data from Pretest and Posttest Results of Concept Understanding

	N	Min	Max	Mean	Std. Deviasi
Pretest Eksperiment Class	36	10	65	40.97	12.295
Posttest Eksperiment Class	36	50	90	66.11	10.150
Pretest Control Class	36	10	55	36.11	11.656
Posttest Control Class	36	25	70	50.83	10.856
Valid N (listwise)	36				

Tabel 2. Descriptive Data on Pretest and Posttest Results of Communication Skills

	N	Min	Max	Mean	Std. Deviasi
Pretest Eksperiment Class	36	10	65	30.61	10.731
Posttest Eksperiment Class	36	45	85	61.81	10.011
Pretest Control Class	36	20	50	35.00	7.464
Posttest Control Class	36	25	75	48.19	11.474
Valid N (listwise)	36				

Where: Min = Minimum, Max = Maximum, and Std. Deviation = Standard Deviation.

Table 3. N-Gain Test Results for Concept Understanding and Communication Skills of Students

Cl	N	Criteria Index Gain (%)			Criteria Normalized N-Gain			
		H	M	L	Pre test	Pos ttest	N-G	Ctg
CU C	36	2,8	25	72,2	36,1	50,8	0,2	R
E	36	5,6	61,1	33,3	41	66,1	0,4	S
CS C	36	0	33,3	66,7	35	38,6	0,2	R
E	36	0	61,1	38,9	49	61,8	0,3	S

Where: CU = Concept Understanding, CS = Communication Skills, Cl = Class, C = Control, E = Experiment, H = High, M = Medium, L = Low, NG = N-Gain, and Ctg = Category.

Based on the results of the N-Gain test in Table 3, it shows an increase in the average value of understanding concepts and communication skills of students in the experimental class to be in the medium category, and in the control class the average value is obtained in the low category. So it can be said that direct PhET virtual experimental learning as a virtual laboratory is less effective for improving students' conceptual understanding because it is at an average of 0.4, while learning by using a print out display of PhET is not effective for improving students' conceptual understanding at an average of 0. ,2. Meanwhile, the use of virtual experimental learning by using PhET virtual experimental learning directly as a virtual laboratory and learning by using printouts of PhET display are not effective for improving students' communication skills because they are on average 0.2 and 0.3.

The independent sample t test is presented in Table 4 to find out whether there is a difference in the mean of the two unpaired samples.

Table 4. Independent Sample t test

Description	Understanding the Concept	of Communication Skills
T_{hitung}	6.17	5.36
T_{tabel}	1.99	1.99
Sig.	0.000	0.000
H_0	Rejected	Rejected

Based on Table 4, the calculated is greater than t table and sig. 0.000 for understanding concepts and communication skills. Based on this, it can be concluded that: there is a difference in the average understanding of students' concepts between the control class and the experimental class, and there is an average difference in students' communication skills between the control class and the experimental class.

The research hypothesis tested in this study is the effect of virtual experimental learning on understanding concepts and students' communication skills on the elasticity and Hooke's law material in Tables 5 and 6.

Table 5. ANOVA Test Results Concept Understanding

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4201.389	1	4201.389	38.043	.000
Within Groups	7730.556	70	110.437		
Total	11931.944	71			

Table 6. ANOVA Test Results Communication Skills

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3334.722	1	3334.722	28.764	.000
Within Groups	8115.278	70	115.933		
Total	11450.000	71			

Based on Tables 5 and 6, research hypotheses about the effect of virtual experimental learning on understanding concepts and communication skills of students in the experimental class and control class. Decision making on the research hypothesis can be seen by comparing the magnitude of the significance with . The significance value (0.000) < (0.05), then H0 is rejected.

This study aims to determine the effect of virtual experimental learning on students' understanding of concepts and communication skills on elasticity and Hooke's law at SMA Negeri 2 Palu by looking at the differences in students' abilities in solving problems of understanding concepts and communication skills. At the beginning of the study, a pretest was given first. Then a final test (posttest) is given to determine the final ability of students and as research analysis data which is then used to see whether there is an influence on understanding concepts and students' communication skills. The questions presented are not the same as the usual practice questions. To solve problems, students must master the things that have been studied previously, namely knowledge, understanding, and skills.

1. The Effect of Virtual Experimental Learning on Students' Concept Understanding

Data from the posttest results in the experimental class and control class, there is a relatively large difference in students' conceptual understanding. The mean of the experimental class is 66.11 and the control class is 50.83. This shows that after being given different treatment between the experimental class and the control class, there are differences and improvements in students' conceptual understanding. The experimental class and control class experienced an increase, but the increase in the experimental class was higher than the control class.

The teacher starts learning by giving apperception to students, then conveys learning materials and learning objectives to be achieved. The study was conducted three times in accordance with

the material of elasticity and Hooke's law (elasticity, Hooke's law, and the arrangement of series and parallel springs) in the experimental class. The questions and problems given to students in each meeting are different. The learning process is carried out virtually with the help of zoom meetings, meeting IDs are distributed to students through the whatsapp group application.

After all students have joined the zoom meeting, students are asked to open the module that has been shared through Google Classroom. After that, the teacher directs students to conduct virtual PhET experiments by accessing the PhET Simulation link in the module. The teacher then guides students to work on the LKPD in the module, this is intended so that students in answering student questions can find solutions to existing questions or problems.

Students are trained to express their opinions by concluding the experiments carried out, this is intended so that in the learning process students can still have a meaningful learning experience. Then students reflect on the results of the experiments that have been carried out, then the teacher and students conclude the learning materials that have been studied.

The use of PhET virtual experimental learning directly as a virtual laboratory in this case students directly access PhET in conducting experiments, providing a new learning atmosphere for students so that students become interested and motivated to take part in learning. Learning virtual experiments can also arouse curiosity, easy to understand, and able to provide challenges for students so that they can make scientific understanding. This happens when students do virtual PhET experiments using PhET interactive simulation software on elasticity and Hooke's law, students are enthusiastic and want to know what happens when a load is hung on a spring, then whether the value of the spring force affects the value of the spring force, and how does it compare? spring constant in series and in parallel.

Learning in the control class is carried out using the whatsapp, google meeting, and google classroom applications, the google meeting link is shared via whatsapp group. In the control class, students are directed to observe the PhET display available in the LKPD in the module.

The understanding of students' concepts in the experimental class is higher because students are given a visualization that is easy to understand. In the worksheets contained in the module, students conduct experiments and analyze the results of virtual PhET experiments, so that students' thinking skills continue to develop, can relate events to the experimental process and build a concept. Meanwhile, in the control class, the control class who participated in learning using the print out of the PhET display, in this case, only observed the PhET display experiment on the module. Students in the control class are not faced with good visualization and problems that occur so that the ability to interpret, analyze, relate problems to one another is lower than the experimental class. In this learning, students play a passive role only by observing the PhET display experiment on the module. This makes students feel bored faster, and do not understand PhET virtual experiments well.

The results obtained in this study are in accordance with the research of Asriyadin, et al. (2018) which concludes that one of the benefits of PhET software media is that students can better understand the learning process because they can see and try out the media used in learning for themselves and it can be done repeatedly. Ramadani & Nana (2020) in their research also confirms that the use of PhET virtual laboratory media is more efficient and makes learning more fun, the concepts taught are more real and easy to understand so as to improve students' conceptual understanding.

Based on the analysis, the average N-gain score is 0.4 which is included in the medium category. Based on the N-gain score data, it is known that there is an increase in students' conceptual understanding scores in the experimental class, meaning that learning using virtual experiments has an effect on increasing students' conceptual understanding. This result is also supported by statistical test analysis on hypothesis testing using the ANOVA formula with a level of = 0.05. From the calculation of the hypothesis obtained that Sig. <0.05 is 0.000 <0.05 in other words the hypothesis H0 is rejected. Based on the results of hypothesis testing, it can be concluded that there is a significant effectof virtual experiment learning on students' understanding of concepts on elasticity and Hooke's law.

Increased understanding of concepts occurs because students are interested and become active in learning PhET virtual experiments. Students are directly involved in the experiment so as to make students active and understand the material better. This research is in line with research conducted by Masita, et al. (2020) who explained that learning using PhET Simulation was in the moderate category, which was proven to be able to improve understanding of concepts. This is also in line with research conducted by Asriyadin, et al. (2018) one of the benefits of the PhET software media is that students can better understand the learning process because they can see and try out the media used in learning for themselves and it can be done repeatedly.

Virtual experimental learning affects students' understanding of concepts because virtual

experimental learning makes learning more interesting which makes students interested and more active in participating in learning with virtual experiments that can increase students' enthusiasm in learning so that it can help understand the concepts being taught. This is in accordance with the research of Hermansyah, et al. (2015) that learning by using a virtual laboratory can have an effect on increasing students' mastery of concepts.

Based on the results of the study, the differences in students' conceptual understanding through experimental learning can help in instilling concepts in students. In the online learning process, teachers experience difficulties because they cannot demonstrate the concept of elasticity and Hooke's law directly, which has an impact on students who cannot do practical work directly in the laboratory. So that by learning virtual experiments using PhET simulation media, students can visualize a physics theory and explore more material which then makes physics more interesting and fun to learn.

2. The Effect of Virtual Experimental Learning on Students' Communication Skills

Based on data analysis in the experimental class and control class, it shows that the highest average score is in the experimental class that applies direct virtual experimental learning as a virtual laboratory. The results of data analysis using the two-average difference test through the independent sample t test at a significance level of 0.05 obtained a comparison value between the group of students who were taught by direct virtual experimental learning as a virtual laboratory and the group of students who were taught using the print out of the PhET display showed that there was a significant difference in the mean of students' communication skills.

Virtual experiment learning activities in the midst of the covid-19 pandemic are an effective choice, so virtual experiment-based learning is well designed and certainly fun for students. Virtual experimental learning is able to develop scientific thinking attitudes by trying, researching, observing and concluding a concept principle. Learning activities are designed to develop science process skills, in this case the communication skills that students have after participating in learning.

Through virtual experiment learning, it is hoped that students can increase knowledge in the form of concepts, scientific methods in the form of process skills, and scientific attitudes. Virtual experimental learning introduces students to the scientific method of learning science from a real laboratory to a virtual laboratory. During learning, students are given knowledge and experience in conducting virtual experiments which can later improve skills to conduct experiments in real laboratories. In virtual experimental learning PhET directly as a virtual laboratory in this case students directly access PhET in conducting experiments, students conduct experiments independently so that virtual experimental learning becomes more meaningful, students have experience and can illustrate concepts, principles and skills of the science process.

The use of virtual experimental learning can improve students' communication skills. The treatment given makes students have competencies that also affect their communication skills. Aspects of student communication skills possessed by students in the learning process, namely, students are able to understand how to process and interpret data from tables to graphs, explain the relationship between mass and length of springs, and explain experiments on elasticity using 2 different springs with different sizes. the same one.

Based on the N-gain score data, it is known that there is an increase in the score of students' communication skills in the experimental class, meaning that learning using virtual experiments has an effect on increasing students' understanding of concepts. This result is also supported by statistical test analysis on hypothesis testing using the ANOVA formula with a level of = 0.05. From the calculation of the hypothesis obtained that Sig. < 0.05 ie 0.000 < 0.05 in other words the hypothesis H0 is rejected. Based on the results of hypothesis testing, it can be concluded that there is a significant effect of virtual experimental learning on students' communication skills on the elasticity and Hooke's law material.

Learning PhET virtual experiments directly as a virtual laboratory is better than learning by using print outs of PhET displays, to improve students' science process skills. Experimental-based learning is a varied learning process and includes activities based on scientific methods, such as formulating hypotheses, planning investigations, carrying out experiments, analyzing and interpreting data, and drawing conclusions.

The improvement of students' communication skills with virtual experimental learning occurs because students are interested and become active in learning, so that they are able to build good communication between teachers and other students. Putri, et al (2018) confirmed in their research that PhET simulation-assisted learning is able to make students more active in participating in learning, and can increase students' interest and process skills. In addition, based on the results of research by Handayani, et al (2021) confirming distance learning by combining google classroom media with PhET simulation can improve students' communication skills. The study also explains that online learning that collaborates with google

classroom and interactive PhET simulations can improve students' communication skills.

Conclusion

Virtual experimental learning has an effect on students' understanding of concepts. Virtual experimental learning makes students able to have meaningful learning experiences, can arouse curiosity, easy to understand, and be able to provide challenges for students so that they can make scientific understanding and so that they can help understand the concepts being taught. Virtual experimental learning has an effect on students' communication skills. Virtual experimental learning is able to develop scientific thinking attitudes by trying, researching, observing and concluding a concept principle, which can improve students' process skills.

Acknowledgements

The authors expressed his gratitude and profound appreciation to all those who were sincerely helped and supported during aonducting and finishing this research.

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