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Online Learning Using PhET Simulation Videos and Real Laboratory Videos for Students' Understanding of the Hydrostatic Pressure Concept

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DOI:10.20527/bipf.v11i3.17273

Received: 27 August 2023 Accepted: 28 December 2023 Published: 5 Januari 2024

Abstract

This study aims to analyze the effect of the PhET simulation video (VSP) and real Laboarturium video (VLN) on high school student's understanding of the concept of hydrostatic pressure in online learning. The research was conducted in three representative schools in Palu City. This study used a pseudo-experimental method by comparing: 1) Experiment class 1 taught based on VSP-VLN design with Experiment class 2 taught based on VLN-VSP design; 2) Experiment class 1 and control class whose learning is based on conventional learning; and 3) experimental class 2 with control class. The determination of experimental classes and control classes in each school was carried out by purposive sampling. The statistical test results for the first case showed no significant difference between Experiment Class 1 and Experiment 2 (significance value greater than 0.05). Meanwhile, between Experiment Class 1 and the control class, there is a difference in the N-Gain value (%). This is supported by a significance value of less than 0.05. A comparison between the Experiment 2 class and the control class also shows differences. The average N-Gain (%) score of Experiment Class 1 and Experiment Class 2 is higher than the average value of the N-Gain (%) of the control class. This study concludes that learning using a combination of PhET simulation videos and real laboratory videos, in any order, can positively influence students' understanding of physics concepts compared to conventional learning in the entire online learning system. Video content can be used online or face-to-face to learn physics concepts directly through simulations and real laboratories.

Keywords: Conventional; Laboratory; Real; Online; PhET; Video

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How to cite: Werdhiana, I. K., Kamaluddin, K., Syamsuriwal, S., & Astuti, N. M. W. (2023). Online learning using phet simulation videos and real laboratory videos for students' understanding of the hydrostatic pressure concept. *Berkala Ilmiah Pendidikan Fisika*, 11(3), 402-416.

INTRODUCTION

The COVID-19 pandemic has affected the learning system in schools and universities. Teachers are faced with the problem of carrying out learning that requires it to be carried out online. Good learning tools are needed for students to understand online learning well. Especially for physics, learning requires

experimental activities to support students' learning process. Learning for experimental activities can be done through a virtual laboratory. Several studies have shown that using virtual laboratories in online learning can provide good results (Azma et al., 2022; Dewa et al., 2020; Fitri, 2022; Tupalesy et al., 2021).



A rapid shift in education from traditional classrooms and labs to virtual laboratories has been experienced worldwide (Lindgren & Johnson-Glenberg, 2013). The popularity of virtual experiments used in physics education has attracted academics to measure their effect on physics learning. Its effectiveness on student learning outcomes, motivation, interest in physics, scientific processes and literacy, and students' critical thinking has been noticed. Martinez et al. (2011) found that learning outcomes for optical materials using hyper-realistic virtual simulations were higher than in traditional laboratories. Zuhri & Jatmiko (2014) found that consistent application of PhET can reduce student misconceptions about static fluid material, Zahara et al. (2015) found that using PhET can improve students' learning outcomes and critical thinking skills on static fluid materials. Better learning outcomes and efficient student understanding of the concept are provided through simulations and labs combined rather than just using simulations or laboratory activities (Jaakkola et al., 2011). The use of a combination of experiments with physical manipulation and experiments with virtual manipulation can improve students' conceptual understanding of the light and color domain (Olympia & Zacharia, 2012), and learning using virtual laboratories and real laboratories has the same influence in improving conceptual understanding of direct current electric circuits for prospective elementary school teachers (Baser & Durmuş, 2010). To use a virtual laboratory or computer simulation is sometimes constrained by teachers' readiness to set up virtual labs or computer simulations and students to utilize computers because not all students have computers; most students use an HP. To overcome this problem, a video of the implementation of the experiment can be made. The video of the

experiment can be watched repeatedly by students.

Video in online learning can positively impact student engagement (Bonafini, et.al., 2017; Lackmann, 2021). Student engagement with forums and videos in online learning can improve their learning outcomes (Bonafini et al., 2017). In addition, using videos can be a useful learning resource for students (Brecht, 2012) and can create meaningful learning experiences for students (Karppinen, 2005). The student learning experience can be enhanced by integrating video-based discussions into online learning (Clark et al., 2015). Asynchronous video benefits online teaching and can increase student interaction and engagement (Lowenthal, 2020). In addition to providing a learning experience, videos contribute to students' motivation and positive self-concept in Physics, Chemistry, and Biology (Richtberg & Girwidz, 2018). Video lectures can increase student satisfaction with learning and increase students' engagement with lesson content because students have control over the media and instructor's presence through video lectures (Ou C. et al, 2019).

Some of the benefits of using videos in the learning described above have not specifically used videos of experimental activities or physics experiments in collecting data that can be used as practical data in online learning. Results of a survey conducted by Klein et al. (2021) identify three categories of data that students analyze in online learning: (i) real data taken from others, (ii) simulated data taken alone, and (iii) own data from real experiments (those recorded on video, remotely controlled, or performed). The data used by students in the study were from video recordings using actual tools and PhET simulation videos.

Based on the experiments observed from the video, the students fill in the student worksheets. This video is used as

a substitute for direct experiments in online learning. Usually, video is used as a substitute for experiments if no equipment is available for real-life experiments. However, video is used on this occasion because it is impossible to conduct experiments directly in online learning.

Video is widely used to replace demonstrations or experiments, as the equipment needed to conduct experiments in real life is unavailable (Kettle, 2020). Online video demonstrations can be more effective for student learning than live demonstrations, allowing students to make more accurate observations and engage with content more effectively in basic physics learning (Kestin et al., 2020). Video instruction and modern technological tools can positively impact student engagement, readiness, and learning outcomes in engineering physics laboratory courses (Suhonen & Tiil, 2016).

Students are more engaged with videos that support laboratory activities than videos that contain learning materials. Students tend to perceive laboratory videos as an important tool to help them complete laboratory assignments. In contrast, lecture videos are considered additional material (Lin et al., 2017). Therefore, it is important to combine material and video of laboratory activities in online learning. To combine material and video, laboratories need to use technology. Suhonen and Tiil (2016) found that using video instruction combined with modern technological tools has a beneficial effect on student engagement, readiness, and learning outcomes in engineering physics laboratory courses. In this study, the video of experimental activities was presented with the material in PPT. This research combines experimental videos using real equipment with experimental videos using PhET simulations (spiritual laboratories). Therefore, the study aims

to determine the effect of learning using PhET simulation and real laboratory videos on high school students' understanding of physics concepts.

METHOD

High school students in Palu City as the population in this study. Research sampling is based on purposive sampling techniques by considering the area where the school is located. Three high schools were selected as samples representing Palu's western, central, and eastern regions. Three classes were selected in each representative school and labeled as experimental class 1, experimental class 2, and control class. There are nine classes, with the number of students presented in Table 1.

Table 1 Total students

School	Class	N
School 1	Experiment 1	10
	Experiment 2	24
	Control	18
School 2	Experiment 1	20
	Experiment 2	32
	Control	25
School 3	Experiment 1	16
	Experiment 2	28
	Control	11

Based on the objectives of the study, a quasi-experimental approach was applied. Quasi-experiments are implemented because they have limited control over independent variables (Neuman, 2014). Experimental group 1 was given learning using PhET simulation video and real laboratory video (VSP-VLN). Experimental group 2 was given VLN-VSP activity. Learning is carried out online, and all laboratory activities are provided as videos. In addition to explanations from teachers, students can learn through videos containing laboratory activities on hydrostatic pressure provided by researchers. For experimental class 1, learning began with PhET simulation videos and continued with Real

laboratory videos, while experimental class 2 was given videos with VLN-VSP sequences. The control class was not treated, so students followed the learning activities as usual. The same physics teacher teaches all three classes at the same school.

Students' understanding of physics concepts is evaluated using concept comprehension tests. The test consists of 8 essay questions covering the concepts of Archimedes' Law, Pascal's Law, and hydrostatic pressure. The test is based on the physics curriculum for high school students. High school physics teachers are involved in the validation process to determine the suitability of the test content to the topics taught in schools. The results of validation and discussion between teachers and the research team stated that all questions followed the content of physics material in the curriculum.

The significance of the difference was measured between classes from the same school. After that, we saw patterns among the sample schools. Statistical tests were conducted to compare 1) experimental class 1 and experimental class 2, 2) between experimental class 1 and the control class, and 3) between experimental class 2 and the control class. At first, there were nine classes involved in this study. However, due to the unprecedented situation due to

COVID-19, learning activities and pretest-posttests are given online, and it is difficult to control the situation. As a result, one class, namely experimental class 1 School 2, was excluded because of the homogeneity of the collected answers. It is suspected that the questions given were only solved by one student and disseminated to other students, so the data could not be used.

N-Gain analysis (%) (percent of normalized gain) was conducted to determine the increase in student understanding after learning. N-Gain is used to measure the effectiveness of learning methods in improving understanding of concepts. To determine the significance of the difference between the N-Gain value (%) between Experiment Class 1 and Experiment Class 2, between Experiment Class 1 and the control class, and between Experiment Class 2 and the control class, the mean difference test. Average difference test using free sample t-test.

RESULTS AND DISCUSSION

Description of Concept Comprehension Test Results

The results of the research presented are the results of pretest and posttest concept understanding tests. Results from the three sample schools are presented in Table 2.

Table 2 Pretest and posttest results of conceptual understanding

School	Class	Mean		Standard Deviation		N-Gain(%)
		Pretest	Posttest	Pretest	Posttest	
School 1	Experiment 1	44.60	61.60	11.82	7.15	47.47
	Experiment 2	53.29	65.38	5.59	3.57	44.45
	Control	40.11	52.61	8.61	9.02	31.51
School 2	Experiment 1	-	-	-	-	-
	Experiment 2	22.06	54.34	5.90	6.97	55.34
	Control	48.72	52.76	3.22	1.96	12.44
School 3	Experiment 1	37.94	56.88	4.89	6.19	44.36
	Experiment 2	39.92	61.14	6.65	8.02	52.61
	Control	43.36	50.09	3.96	5.48	17.96

Table 2 shows each class's average N-Gain (%) is different. The average N-Gain (%) of the experimental class was higher than that of the control class. This means that the increase in the concept understanding of experimental class students is higher than that of the control class. This difference is because learning is given in the experimental class using a combination of PhET simulation videos with real laboratory videos, while the control class is without video. The findings of this study contribute to research that applies PhET in Physics learning. This finding is by research using PhET that PhET simulation can improve understanding of physics concepts (Elisa et al., 2017; Fathurohman et al., 2018; Hasibuan & Abidin, 2019).

However, we cannot confidently confirm that this study's results reinforce previous studies' findings, as the situation is different. The difference with previous research is in the use of PhET and the implementation of learning. Previous research used PhET simulation in face-to-face learning, while ours used PhET video in online learning.

The difference in each class's average N-Gain (%) needs to be tested for significance. Statistical tests were carried out based on data from each school to determine the significance of these differences. The results of the normality test can be shown in Table 3. The whole class's N-Gain (%) value is normally distributed, with a significance value greater than 0.05.

Table 3 N-gain data normality test

School	Class	Kolmogorov-Smirnov ^a		Shapiro-Wilk			
		Statistic	df	Statistic	df	Statistic	df
School 1	Experiment 1	.262	10	.050	.914	10	.306
	Experiment 2	.114	24	.200 *	.967	24	.583
	Control	.139	18	.200 *	.948	18	.398
School 2	Experiment 1	-	-	-	-	-	-
	Experiment 2	.095	32	.200 *	.974	32	.616
	Control	.201	25	.011	.920	25	0,051
School 3	Experiment 1	.187	16	.138	.922	16	.184
	Experiment 2	.146	28	.131	.961	28	.375
	Control	.230	11	.109	.880	11	.104

Significance Differences between Experiment Class 1 and Control Class, and Experiment Class 2 and Control Class

Experiment class 1 and control class

The control class's average N-Gain (%) was smaller than that of Experimental Class 1. The group significance test and self-test results are presented in Tables 4 and 5.

Table 4 Group statistics for n-gain

School	Class	Mean	Standard Deviation	Average Standard Error
School 1	Experiment 1	47.74	13.88	4.39
	Control	31.51	18.42	4.34
School 3	Experiment 1	44.36	15.81	3.95
	Control	17.96	14.12	4.25

Table 5. Independent Samples Test for N-Gain(%)

School		Uji Levene for Varians Equivalence		Uji t for Average Equivalence		
		F	Sig.	T	df.	Sig.(2-tailed)
School 1	The same variant is assumed	0,93	0,34	2.42	26	0,023
	The same variant is unassumed.			2.63	23.38	0,015
School 3	The same variant is assumed	0,26	0,62	4.45	25	.000
	The same variant is unassumed.			4.55	23.19	.000

The data variance of N-Gain (%) Class Experiment 1 and Class Control is the same or homogeneous, as evidenced by the significance value (sig.) The Levene Test for Variance Equality is in Table 5. The same variance is assumed to be used to interpret the t-test for mean equality. It gives the result of a meaningful (significant) difference between the N-

gain (%) of Class Experiment 1 and Class Control.

Experiment 2 and Control Class

Class Experiment 2 achieved a higher average N-Gain than Class Control. The results of comparing these classes are presented in Tables 6 and 7.

Table 6 Group statistics for n-gain

School	Class	Mean	Standard Deviation	Average Standard error
School 1	Experiment 2	44.45	11.74	2.40
	Control	31.51	18.42	4.34
School 2	Experiment 2	55.34	12.84	2.27
	Control	12.44	7.10	1.42
School 3	Experiment 2	52.61	18.43	3.48
	Control	17.96	14.12	4.25

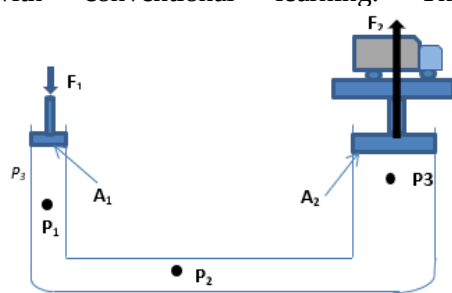
Table 7 Independent sample test for n-gain

School		Levene Test for Varians Equivalence		T-test for average equivalence		
		F	Sig.	T	df.	Sig. (2-tailed).
School 1	The same variant is assumed	4.041	0,051	2.78	40	.008
	The same variant is unassumed			2.61	27.07	.015
School 2	The same variant is assumed	6.508	.014	14.99	55	.000
	The same variant is unassumed			16.02	50.11	.000
School 3	The same variant is assumed	0.91	0,35	5.61	37	.000
	The same variant is unassumed			6.30	23.92	.000

Table 7 shows that the signification value (Sig.) of the Levene Test for variance equivalence for Schools 1 and 3 is greater than 0.05, while for School 2, it is less than 0.05. The t-test for all schools revealed a significant difference between

the N-gain (%) of experimental class 2 and the Control class in the three schools. Regarding the first research question, whether there is an effect of learning using PhET simulation and actual laboratory on high school student's understanding of physics concepts, the

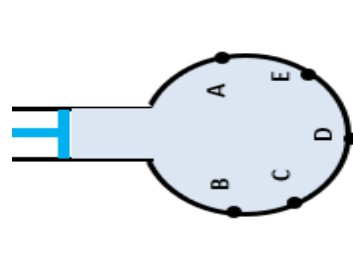
findings illustrate that the N-Gain (%) value of experimental class 1 and experimental class 2 in all schools is greater than the control class. Furthermore, the t-test revealed that there were significant differences between the experimental class and the control class in all schools. This shows that experimental class students, both taught with the help of VSP-VLN and VLN-VSP combinations, understand the concept of hydrostatic pressure better than control class students who are taught with conventional learning. This



(a)

Figure 1 (a) Questions about the hydraulic lifting principle (b) Questions about hydraulic piston

confirms that the use of a combination of VSP and VLN influences students' understanding of physics concepts. It should be noted that all learning activities are carried out online. Interestingly, even though students only see laboratory activities, the results of this study also prove the positive impact of the combination of VSP and VLN on students' understanding of concepts. The answer illustration of students in experiment class 1, experiment class 2, and control class can be seen in Figures 1a and 1b.



(b)

Two of the eight posttest questions are about Pascal's Law concepts. Figures 1a and 1b are physics problems related to Pascal's Law. Figure 1a asks students to explain which system (P_1 , P_2 , or P_3) has the least stress. Meanwhile, students are asked to explain in Figure 1b which holes (holes A, B, C, D, and E are identical) will spit out the farthest water if the piston is pressed.

Students of experimental group 1 and experimental group 2 had a better understanding of Pascal's Law than the control group students. Students in the experimental group answered more correctly than their peers in the control group. For example, control group students think the greatest pressure is on the small piston for the problem shown in Figure 1a. In addition, for the question Figure 1b, they assume that the water exits farthest at point D because point D

is located farthest from the piston. Meanwhile, experimental group students can answer these questions correctly because they have witnessed the implementation of similar concepts through actual experimental videos and virtual experimental tools.

Despite the positive impact, the interpretation of the N-Gain value (Table 2), based on Hake's qualification (1998), revealed that the effectiveness of the learning process in experimental classes 1 and 2 of all schools was in the medium category. Meanwhile, learning in the control class is not effective. It could be because learning activities are carried out entirely online. Laboratory activities cannot be carried out directly by students. Students only observe the experimental video before working on the student worksheet that has been provided. Topics about static fluids are well-packaged and

formulated so students can learn independently. In addition, experimental videos can be watched repeatedly by students. This method is quite helpful in online learning.

Significance Difference between Experimental Class 1 and Experimental Class 2

The mean N-Gain (%), standard deviation, and t-test results of Experiment 1 and Experiment 2 classes are shown in Tables 8 and 9. Based on the Levene Test for variance equality in Table 9, the significance value (sig.) is greater than 0.05. This means that the N-Gain data variance (%) for experiment class 1 and experiment 2 is homogeneous for both schools. Therefore, the same variant assumption is used to interpret the t-test results. Since the significance value is greater than 0.05, there is no difference in N-Gain (%) between the two classes. This study's results align with previous studies that found no meaningful impact of the sequence of real laboratories and virtual laboratories on students' conceptual understanding activities (Chini et al., 2012; Toth et al., 2009). However, we cannot confidently

confirm that this study's findings reinforce previous findings.

The different situations of how students learn through PhET and Real Labs in this study need to be considered. For example, online learning certainly has many obstacles. Student activity in the learning process cannot be fully controlled. Also, students may face obstacles such as unstable internet connections or networks. Students' understanding of concepts is based solely on their interpretation after watching the video. In addition, the impact of merging real and virtual laboratories and their sequence depends on many factors, such as topics, initial knowledge, and students' conceptions (Atanas, 2018; Chen & Chang, 2016). As a result, students may have different preconceptions about and how to interpret the topic. It is a challenge for teachers to overcome these issues to improve their understanding of concepts throughout the online education system. These constraints also affect student learning outcomes. Another obstacle is in carrying out learning evaluations. When students are given tests, teachers cannot fully control them, making it difficult for them to do the given assignment.

Table 8 Group statistics for n-gain

School	Class	N	Mean	Standard Deviation	Average Standard Error
School 1	Experiment 1	10	47.74	13.88	4.39
	Experiment 2	24	44.45	11.74	2.40
School 3	Experiment 1	16	44.36	15.81	3.95
	Experiment 2	28	52.61	18.43	3.48

Table 9 Independent sample test for n-gain

School		Levene Test for Varians Equivalence		T-test for mean equivalence		
		F	Sig.	t	df.	Sig. (2-tailed).
School 1	The same variant is assumed	0.438	0.51	0.71	32	0.49
	The same variant is unassumed			0.66	14.65	0.52
School 3	The same variant is assumed	0.35	0.56	-1.50	42	0.14
	The same variant is unassumed			-1.57	35.47	0.13

Although there are obstacles in carrying out learning evaluations, it generally shows that using experimental videos in online learning provides students with a better understanding of hydrostatic pressure than without videos. Because the use of video in online learning gives students more interaction than just presenting text (Clark et al., 2015), students prefer videos that support laboratory activities over videos that display learning materials (Lin et al., 2017).

The video used in this study presents experiments on hydrostatic pressure, and students cannot manipulate or change experimental data, so students only do student worksheets based on the data displayed on the video. However, through video, students can better understand the concept of hydrostatic pressure in online learning. Therefore, it is necessary to consider using experimental videos in online learning. Especially Video experiments with real equipment while Video PhET can be replaced by using PhET simulation offline or online.

CONCLUSION

The learning stages in this study were carried out entirely online. Therefore, laboratory assistants carry out experiments using practicum tools in the Physics lab, and videos are made based on these activities. The same phase is also applied to virtual experiments. Students then observe this experimental video before working on the worksheets that have been provided.

The findings revealed that although students can only watch experimental videos in online learning, using PhET simulations (VSP) and real practicum equipment (VLN) can provide a better understanding than learning without videos. The results of this finding are supported by the test results of the average difference in N-Gain values (%) between experimental class 1 with the

control class and experimental class 2 with the control class. The results showed significant differences between experimental classes and control classes. However, between experimental class 1 and experimental class 2, there was no difference in improving students' understanding. In conclusion, combining PhET simulation Video and real laboratory video can increase students' understanding of physics concepts in online learning. Although the study was conducted in three schools, generalizations cannot be drawn. Similar research should be built in the future with schemes where students learn from videos containing real and virtual experiments. However, teachers can directly intervene in the learning process to question and correct students' understanding. This will enrich information about the effectiveness of VLN and VSP on students' understanding of concepts. Nevertheless, despite the limitations of this study, it should be underlined that providing videos to students consisting of lab simulations and real labs can improve students' understanding of hydrostatic pressure. Video content can increase student participation in learning because they can learn physics concepts through simulations and relate them to real-life phenomena through real labs.

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