

EFFECTIVENESS OF USING VIRTUAL LABORATORY SIMULATIONS IN PHYSICS EDUCATION BY COMPARING THE ACCURACY OF GRAVITATIONAL ACCELERATION RESULTS

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ABSTRACT: Conducting laboratory experiments is crucial for comprehending physics theories and their practical applications at any educational level. Virtual laboratory experiments have become more popular because of developments in technology. These experiments offer numerous benefits over traditional physical laboratories, including increased flexibility, cost-effectiveness, accessibility, and safety. When considering these advantages, it is important to take into consideration how accurate virtual laboratories are in enhancing students' educational levels when compared to physical laboratories. Hence, this study mainly aims to observe how the quality of physics education at NSBM Green University, Sri Lanka, can be enhanced by introducing virtual laboratories. To determine the gravitational acceleration (g), 29 Engineering Foundation students participated in the Simple Pendulum Oscillation Experiment as part of their Physics course. The PhET platform was used to conduct the virtual laboratory, while the physics lab was used to conduct the physical laboratory. According to the results obtained in both physical and virtual laboratories, it was observed that the mean, median and mode 'g' values obtained in both methods are closer to the actual gravitational acceleration value. But the 'g' values obtained from the physical laboratory consists of higher variability and a wide range of results. This indicates that, in comparison to physical laboratories, virtual laboratories provide more consistent and stable results with less variability. But physical laboratories help the students to improve their critical thinking and problem-solving abilities and to understand theoretical concepts. Therefore, this study shows that a combination of physical and virtual experiments in a variety of other disciplines with different kinds of virtual platforms can be further expanded for the advancement of educational technology.

Keywords: oscillation experiment, physical laboratories, physics education, virtual laboratories

1. INTRODUCTION

Virtual laboratories have gained popularity in physics education as technology continues to advance. It encompasses real-world problems and is more attractive because studies mainly focus on various aspects such as student engagement, learning outcomes, and practicality (Alsharif, 2022). Virtual laboratories give more chances to become familiar with the platform, increase confidence and can handle more complex laboratories (Umukozi, Yadav, & Bugingo, 2023). Virtual laboratories are easier, simpler, more interesting and can handle simultaneous participation by multiple students compared to traditional hands-on laboratory experiments (Mihret, Alemu, & Assefa, 2022) and have fewer restrictions on how they can conduct the laboratory according to their availability and requirements (Asiksoy, 2023). However, considering these factors, academics must identify the accuracy of the virtual laboratories rather than performing in conventional laboratories. To analyze the accuracy of the results, this study was conducted using a simple pendulum oscillation physics experiment. The main aim of this study is to enhance the quality of educational technological advancement by implementing virtual laboratories of physical science education at NSBM Green University, Sri Lanka.

2. METHODOLOGY

A sample of 29 Engineering Foundation students studying Physics-1 as a core module of their Foundation Program at the Faculty of Engineering, NSBM Green University, participated in this laboratory experiment. Each student performed a physical experiment in the physics laboratory and a virtual experiment using the PhET platform. For both laboratories, all the parameters were set as common (Except environmental factors); the weight of the simple pendulum was 0.5 kg, and lengths (L) of the pendulum were 0.4 m, 0.5 m, 0.6 m, 0.7 m, 0.8 m, and 0.9 m. The time-period (T) was measured and recorded by making 25 oscillations for each length. Obtaining the results of the virtual laboratory, the T^2 against L graph was plotted using Microsoft Excel 2016, and results obtained from the physical laboratory, a graph was plotted manually to determine the gradient of the graph. During

the physical laboratory session, manual graph plotting allowed students to obtain hands-on experience with traditional data analysis techniques with graph interpretation. In the virtual laboratory, Microsoft Excel's efficiency aligned well with the virtual lab environment, making it a suitable tool for data analysis. Then the gravitational acceleration was calculated for both virtual and physical laboratories and both values were submitted as a lab report along with a questionnaire. Using these test results, descriptive analysis including mean, median, mode, and standard deviation was calculated to summarize the data from IBM SPSS Statistics. Additionally, t-test was employed to compare the effectiveness of physical laboratory result versus virtual laboratory result. Fig. 1 shows the detailed methodology adopted for the study.

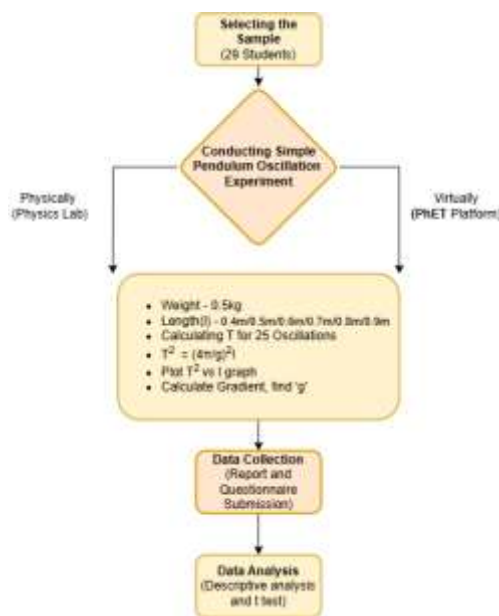


Fig. 1. Flow Chart of Methodology

3. RESULTS AND DISCUSSION

Fig. 2 shows the results obtained from the students' questionnaire. Based on these results, all the students have responded that physical laboratories have improved their critical thinking and problem-solving abilities more than virtual laboratories. 59% of students stated that physical laboratories helped them in understanding theoretical concepts, while 41% of students said that virtual laboratories are good in understanding the theoretical concepts. Compared to virtual laboratories, physical laboratories are more time-consuming. In terms of repeatability, 76% voted that virtual laboratories are more repeatable than physical laboratories. When comparing the obtained gravitational acceleration values, 73% of students received more accurate values for 'g' from the virtual experiment, and 27% of students obtained accurate 'g' values from the physical experiment.

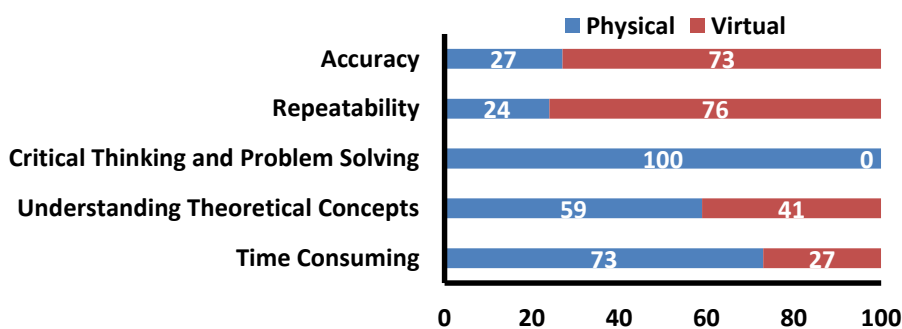


Fig. 2. Students' Survey Results on Physical and Virtual Laboratory Experiments

Table 1. Results of Descriptive Analysis

Variable	No of Students	Mean	SE Mean	St.Dev	Minimum	Median	Maximum	Mode	P Value
Physical Lab	29	9.8655	0.1136	0.6117	7.900	9.860	12.260	9.860	0.839
Virtual Lab	29	9.8417	0.0249	0.1341	9.410	9.860	10.300	9.870	0.839

The standard value of the acceleration due to gravity is 9.80665 m/s^2 . When comparing the percentage error between the actual and experimental results, the physical laboratory has 0.60% and the virtual laboratory has 0.36%, which shows that virtual laboratories provide more accurate results than physical laboratories. The mean gravitational acceleration of physical laboratory was 9.8655 m/s^2 with a standard deviation of 0.6117, which shows relatively higher variability in the data set, while 9.8417 m/s^2 for virtual laboratory has a lower standard deviation of 0.1341. According to the analysis, the results obtained from virtual laboratory were more consistent compared with physical laboratory.

When considering the range of the values, the physical laboratory has a wide range of gravitational acceleration values, where minimum is 7.90 m/s^2 and maximum is 12.26 m/s^2 (Fig. 3). This higher range indicates that some data of the set has dropped off from the exact value. This may cause human errors, atmospheric errors and instrumental errors. Compared with virtual laboratory, the minimum value is 9.41 m/s^2 and maximum value is 10.30 m/s^2 reflecting the controlled lab environment of the virtual laboratory. Both physical and virtual laboratories have the same median value of 9.860 m/s^2 , while the mode for virtual and physical laboratories are 9.87 m/s^2 and 9.86 m/s^2 respectively. That indicates that both data sets are quite similar and most of the values are clustering around each other. The p value of t-test which is 0.839 much greater than the common significance level threshold (0.05) and it fails to reject the null hypothesis. Therefore, this proves no statistically significant difference can be identified between the means of two laboratories. This study can be expanded to include more physical and virtual experiments in different disciplines by using different virtual experiment platforms for improved results.

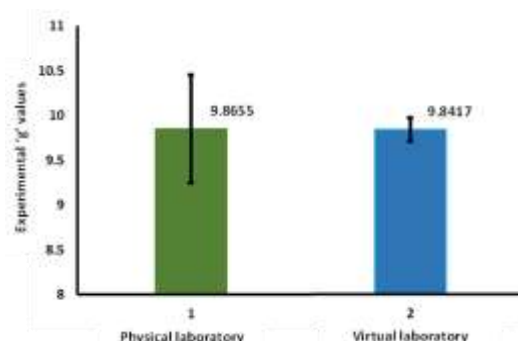


Fig. 3. Comparison between Physical and Virtual Experimental Results

4. CONCLUSION

The gravitational acceleration value measured by physical and virtual laboratories for the simple pendulum experiment shows that both laboratory experiments provide accurate results, while the virtual laboratory provides more consistent and reliable measurements with less variability. Moreover, compared to the virtual laboratory, the physical laboratory consists of higher variability and a wide range of results due to real-world experimental conditions and errors caused by humans and equipment. Both laboratory types exhibit similar patterns, with comparable median and mode values. This study proves that virtual laboratories are more stable and have a reproducible learning environment, while physical laboratories provide real-world environmental attributes to help students understand theoretical concepts. Therefore, a combination of both methods can enhance the learning environment, gaining experience, leading to better understanding skills and practical skills, and improving the quality of education at NSBM Green University.

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