The usefulness of LabXChange virtual lab and PhyPhox real lab on pendulum student practicum during pandemic

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Abstract. Virtual Laboratory (virtual lab) is a series of virtual experiment laboratories that have been designed and programmed to be used by students for practicum, especially during the Covid-19 pandemic. The virtual lab is helpful for student to build content knowledge which usually they do in real practicum activities. The virtual lab is arranged systematically. Therefore, the result should be close to the real value. Here we report our study on pendulum whether the virtual lab experiment yield the same result as the real laboratory (real lab). We compare both results of experimental data using data analytics and also graphic analytics. The results from the study, shows that there is no significant difference between virtual lab and real lab. Thus, the virtual laboratory is a comparable pendulum experimental result for students doing a remote practicum in physics.

1. Introduction
The industrial revolution has a global and comprehensive impact on all areas of human life, including education. This is marked by the increasing various technology and information in human life until it is adopted in the world of education in a form of a virtual laboratory (virtual lab). The virtual lab is a sequence of virtual experiment that allows students to accomplish practicum and to explore concepts and theories without stepping into a physical science lab. Moreover, the presence of a virtual lab is a big hand during this pandemic.

There are many advantages of using virtual lab [1], such as implementing time-consuming experiments in a shorter period, conducting dangerous experiments in a safe setting, recreating events that would be hard to witness in a physical laboratory, and serving as a cost-effective alternative to expensive laboratories [2]. Other benefit of virtual lab may carrying out laboratory activities in terms of students’ practicum to help them to understood Physics concept.

One of tools that can be used to help practicum is PhyPhox (as an acronym for physical phone experiments), a smartphone-based experiments for physics [3]. The PhyPhox application can be used for various learning models and is practically used as a real laboratory (real lab). Previous research shows that practicum using PhyPhox application can make students independent in conducting an experiment [4]. It also can effectively and efficiently improve students’ understanding.

There are many various of virtual lab that can be used other than a smartphone application of real lab. LabXchange is an online community for learning, sharing, and collaboration. It curates and creates world-class digital content, delivered on a free online platform that lets you integrate your learning and research experiences [5]. There are several physics practicum and simulation that can be used.
Learning physics consists of simple, complex, and abstract concepts which are connected [6,7]. Therefore, physics are related to laboratory activities, an important and sacred part of science education [8,9]. One of the subjects is simple harmonic motion, a move back and forth around an equilibrium point contained in the motion of a pendulum [10]. The period of a pendulum for amplitudes less than about 10º can be found using equation below.

\[ T = 2\pi \sqrt{\frac{l}{g}} \]  

which

\[ T = \text{period of pendulum} \]
\[ l = \text{length of the negligible wire / rope} \]
\[ g = \text{gravitational constant about 9.8 m/s}^2 \].

Pendulum is defined to have an object that has a small mass, also known as the pendulum bob, which is suspended from a light wire or string. This work report a study of a pendulum practicum generated by the virtual Lab supported by LabXChange compare to the real lab supported by PhyPox.

2. Method

The research was conducted using an experimental method with laboratory activities on the pendulum. Experiments were carried out virtually using LabXChange media. The data obtained will then be analyzed quantitatively and qualitatively manually. The research flow can be seen in Figure 2.

![Figure 1. Illustration of pendulum.](image)

![Figure 2. Research flowchart.](image)
the length of the rope. The second stage is the observation stage which is carried out on the rope lengths of 0.20 m, 0.40 m, and 0.60 m. The third stage is observing period changes in the length of the rope that have been measured and determined. The fourth stage is observing the period behaviour that occurs in each rope length. The experiment was carried out 10 times in order to get a suitable accuracy value and accurate uncertainty value. A real lab was conducted to obtain comparative data. The tools and procedures are adapted to the experiments carried out in the virtual lab so that they get the same data as the virtual experiment.

3. Virtual lab and real lab results
Research in the real lab was carried out with the same entire series of experiments as the virtual lab to obtain the similarity and validity of the appropriate data, and also did not get a high error value. The real lab experiment went through several stages, namely determining the pre-determined length of the rope, then installing a bow to determine the angle used as can be seen in Figure 3.

![Figure 3](image)

**Figure 3.** Researchers are conducting research on rope length (a) 0.50 m, (b) 0.60 m, (c) 0.70 m, (d) 0.80 m, (e) 0.90 m, (f) 1.0 m under maximum $\theta$ of 10° between amplitude and equilibrium position with a negligible mass of rope.

By using PhyPhox on a pendulum, this experiment will get the most accurate period values possible in real lab experiments which can be seen in Table 1.

| Rope Length (m) | Data taken of pendulum period (s) | Mean of period (s) |
|----------------|---------------------------------|------------------|
| 0.50           | 1.17 1.19 1.18 1.08 1.18 1.19 1.18 1.17 | 1.17 1.159       |
| 0.60           | 1.29 1.28 1.26 1.29 1.23 1.27 1.26 1.27 | 1.27 1.268       |
| 0.70           | 1.45 1.45 1.40 1.31 1.40 1.40 1.40 1.45 | 1.45 1.402       |
| 0.80           | 1.61 1.67 1.73 1.67 1.67 1.61 1.73 1.73 | 1.73 1.676       |
| 0.90           | 1.77 1.84 1.90 1.93 1.84 1.90 1.84 1.77 | 1.77 1.840       |
| 1.00           | 2.07 2.21 2.01 1.96 2.01 2.01 2.21 2.21 | 2.21 2.097       |

Table 1 shows that there is an increase in the average value of the period depending on the length of the rope in various ways. As the length of the rope increases, it gives a constant increase in the period value for each difference in the length of the rope. A constant increase in period as the length of the rope increase is expected by theory as shown in equation 1. The value of the increase in the period to the rope length can be seen in Figure 4.
Figure 4. Effect of rope length on period in real lab.

The increase in the graph is not very significant and tends to decrease at the 0.9 meter length of the rope but there is an increase again. Standard deviation and error values obtained from each length of rope produce values that can be seen in Table 2.

Table 2. Standard deviation and error values.

| Rope Length (m) | Standard Deviation | Error Values (m) |
|-----------------|--------------------|------------------|
| 0.5             | 0.042282121        | (1.16 ± 0.01)    |
| 0.6             | 0.017511901        | (1.27 ± 0.01)    |
| 0.7             | 0.053913511        | (1.40 ± 0.02)    |
| 0.8             | 0.052535702        | (1.68 ± 0.02)    |
| 0.9             | 0.057735027        | (1.84 ± 0.02)    |
| 1.0             | 0.102203501        | (2.10 ± 0.03)    |

There is an insignificant difference between the results of data calculations and the results of PhyPhox calculations, the graph shown in Figure 4 to represent Table 1 can be seen in Figure 5, namely the graph produced by PhyPhox.

Figure 5. Graph of the period on Phyphox for (a) rope length 0.50 m, (b) rope length 0.60 m, (c) rope length 0.70 m, (d) rope length 0.80 m, (e) rope length 0.90 m, (f) rope length 1.0 m.
The results of these differences are due to several factors, including human error when conducting pendulum experiments. The results of accuracy in real lab experiments can be seen in Table 3 that calculated using Equations 2 and 3.

\[
\text{Period Error} = \frac{\text{measurement} - \text{reference}}{\text{measurement}} \times 100\% \quad (2)
\]
\[
\text{Precision} = 100\% - \text{Error} \quad (3)
\]

Virtual lab experiments will be carried out on LabXChange with the pendulum material and variables used in virtual experiments will be adjusted to the real lab in order to create compatible data validity. The virtual lab experiment can be seen in Figure 6.

![Figure 6. Example of Virtual Lab Experiment on LabXChange in 0.6 m rope length.](image)

Virtual laboratory experimental data with the same variables as the real lab in order to create data similarity can be seen in Table 4.

| Rope Length (m) | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 0.5            | 1.14| 1.14| 1.14| 1.14| 1.14| 1.14| 1.14| 1.14| 1.14| 1.14  |
| 0.6            | 1.55| 1.55| 1.55| 1.55| 1.55| 1.55| 1.55| 1.55| 1.55| 1.55  |
| 0.7            | 1.67| 1.67| 1.67| 1.67| 1.67| 1.67| 1.67| 1.67| 1.67| 1.67  |
| 0.8            | 1.79| 1.79| 1.79| 1.79| 1.79| 1.79| 1.79| 1.79| 1.79| 1.79  |
| 0.9            | 1.90| 1.90| 1.90| 1.90| 1.90| 1.90| 1.90| 1.90| 1.90| 1.90  |

Table 3. Accuracy in real lab.

Table 4. Virtual lab data on 0.4 kg pendulum mass and 6° angle.
Table 4 shows that there is an increase over the period depending on the length of the rope. As the length of the string from the pendulum increases, the period produced will increase as well as the multiple of the length of the string used. There are no changes that vary in the use of the virtual lab, because the virtual lab is a laboratory activity that has been programmed in such a way using measurements tested through a real lab [11]. The value of the increase in the period to the rope length can be seen in Figure 7.

![Figure 7. Effect of rope length on period in virtual lab.](image)

The constant change in period indicates that there is an effect of the length of the string on the pendulum period. In multiples of the length of the rope along the 0.50 there is an increase in the period in multiples of 0.41 m. The graph results obtained in Figure 6 are in line with the research conducted by Kuczmann [12] which shows linear results with changes in the length of the rope. Another similar result is in Dalgarno's [13] research, in his research getting constant results from the use of a virtual laboratory because the results set have been designed in such a way that there are no changes unless new variables are added in further development. Sugiana [14] also mentions that the results from using a virtual laboratory get the same results without any changes in the data, this causes the use of a virtual laboratory to be good for understanding basic concepts without further development. There is a difference in comparison between the measurement results in both the real lab and the virtual lab. The comparison between real lab and virtual lab can be seen in Figure 8.

![Figure 8. Comparison of period to rope length between real lab and virtual lab.](image)
Figure 8 shows the resulting comparisons are only slightly different and not too significant but these differences occur due to human error when conducting experiments and also inadequate tool calibration. The result of the percentage comparison between real lab and virtual lab can be seen in Table 5 that calculated using equations.

\[ \text{Difference} = \left( \frac{\text{Real Lab} - \text{Virtual Lab}}{\text{Real Lab}} \right) \times 100\% \]  

(4)

Table 5. Comparison between real lab and virtual lab.

| Rope Length (m) | Difference (%) |
|-----------------|----------------|
| 0.5             | 0.016          |
| 0.6             | 0.022          |
| 0.7             | 0.19           |
| 0.8             | 0.06           |
| 0.9             | 0.032          |
| 1.0             | 0.04           |

In this comparison, it can be seen that the comparison value between real lab and virtual lab produces an insignificant difference which is still at the <1% level. So the use of a PhyPhox-based real lab with a LabXChange-based virtual lab will produce results that are not much different. According to Pierratos [15] in his research using PhyPhox stated that the use of PhyPhox has been designed in such a way with a calibrated sensor so that it does not produce an error value that is too high. Meanwhile, virtual lab is an integrated laboratory activity instrument that has been designed in such a way and has been determined based on the value of real lab experiments [16]. In addition, the virtual lab is a research that uses digital measuring instruments that have been regulated and calibrated, so that the results of the virtual lab measurement precision get high results and low error values, even almost reaching 0% [11,17].

4. Conclusion
In the comparison experiment of LabXChange-based virtual lab with Phyphox-based real lab, the comparison value is not too significant and not much different between the two. This difference is found in the values of 0.08% for a 0.20 meter long rope, 0.025% for a 0.40 meter long rope, and 0.06% for a 0.60 meter long rope. Comparison between the two laboratory activities, the error value is equally small, especially in the real lab, which is getting an error value of 0.13% for a 0.20 meter rope length, 0.09% for a 0.40 meter rope length, and 0.0077% for rope length 0.60 meters. caused by Human Errors that occurred during the study. IoT and virtual lab can be used because of the increased comparison between IoT and Virtual Lab which is almost the same as the error value (1.016 ± 0.007) s on a 0.20 m pendulum, (1.39 ± 0.09) s on a 0.40 m pendulum, and (1.54 ± 0.07) s on a 0.60 m pendulum. Based on the results of this study, real lab and virtual lab can be used because the comparison results between real lab and virtual lab are almost similar. However, in the real lab, the results found will always vary according to field conditions compared to the virtual lab which has been systematically programmed so that the results obtained will always get the same number. Thus, this virtual lab is considered suitable for use during the Covid-19 pandemic or on online learning.

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