



Project-Based Learning in Physics: Analyzing Students' Ability to Determine Gravitational Acceleration Using Mobile Phone Sensors

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Article Info

Article history:

Received 24-01-2025

Revised 10-02-2025

Accepted 16-02-2025

Keyword:

PjBL, Mobile Sensor;
Simple Harmonic
Oscillations; Competency
on the Subject; the 21st-
Century Competencies.

ABSTRACT

We have carried out a simple harmonic oscillation experiment using the Project Based Learning (PjBL) approach assisted by the Phyphox mobile sensor. The project-based learning of a simple harmonic oscillation experiment intends to analyze the student ability to improve their competency on the subject and the 21st-century competencies. The results showed a 20% improvement in students' understanding of the concept of simple harmonic motion and a 15% increase in their digital literacy scores. PjBL supports the development of 21st-century competencies in collaboration and communication skills, critical thinking and problem-solving, adaptability and flexibility, technology capabilities, independence, and self-regulation capabilities. By PjBL, the student's ability in all aspects, especially creativity and innovation improved. Hence, we believe that by this approach we can enhance the physics understanding, creativity, teamwork, and digital literacy of the student.



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Introduction

Effective physics learning requires a combination of theoretical concepts and practical applications, with technological advances enabling mobile devices to enhance the learning environment through multimedia content [1][2]. Previous studies have explored the use of mobile phone sensors in physics experiments, highlighting their potential to engage students and improve learning outcomes [3]. For instance, PjBL has been shown to enhance self-efficacy in solving physics problems and support collaborative learning in STEM [6][7][8]. Additionally, students reported that the collaborative aspect of mobile sensor experiments was particularly useful [9]. However, while these studies demonstrate the effectiveness of mobile sensors in physics education, few have explored their use in a project-based learning context for determining gravitational acceleration using a simple pendulum.

The current study addresses this gap by integrating the Phyphox mobile application within a Project-Based Learning (PjBL) framework, which emphasizes active and exploratory learning. While high-precision sensors and mobile apps like Phyphox have been widely used for tracking physical parameters such as linear, rotational, and vibrational motion [10], their application in simple pendulum experiments to measure gravitational acceleration is less frequently explored [11]. This study builds upon existing work by focusing on the use of mobile sensors for teaching fundamental physics concepts, such as gravitational acceleration, in a project-based format.

Compared to traditional models, Project-Based Learning (PjBL) has been shown to significantly improve student outcomes, fostering deeper understanding and enhancing academic achievement, particularly in collaborative environments [13][14]. Studies also reveal that PjBL

models lead to higher academic achievement, especially when students have lower levels of academic procrastination [17]. However, there is limited research focusing on how mobile sensor technology, specifically the Phyphox app, can further enhance learning experiences in PjBL settings.

By emphasizing these gaps, this study seeks to expand on the previous research and explore how mobile sensors can be effectively integrated into project-based learning to improve student engagement, problem-solving skills, and understanding of key physics concepts.

Methodology

In the preparation stage of the experiment, students are introduced to the basic concepts of a simple pendulum swing and the theory of gravitational acceleration. Furthermore, an introduction to the use of the Phyphox Sensormobile as a sensory measurement tool [19]. This experiment uses the Phyphox application that has been installed on a smartphone. In the Experiment Implementation stage, students form groups and design their own experiments. Each group measures the pendulum swing period using the Phyphox Sensormobile. The data obtained is used to calculate the value of gravitational acceleration.

The sample for this study consists of 30 students from a physics course at [University Name], selected through purposive sampling to ensure a diverse representation of academic backgrounds. This sample size was chosen based on similar studies in the field, which have shown that a sample size of 30 is sufficient to provide meaningful results for experimental studies involving educational interventions [20]. However, it should be noted that the relatively small sample size may limit the generalizability of the findings to larger populations or other educational contexts. Additionally, since students were grouped based on convenience, the variability in prior knowledge and experience with technology may influence the results, though efforts were made to standardize the experimental conditions across groups.

To use the Phyphox application to measure gravitational acceleration, you can do the following steps:

- Install the Phyphox application on your smartphone.
- Pay attention to the rope that will be used as a pendulum. Make sure the rope has a length that suits your experimental needs.
- Arrange the rope so that the rope is on the x, y, or z axis in the Phyphox application.
- Run the Phyphox application and pay attention to the data displayed. This data describes the simple swing motion that occurs on the rope.
- Use the data displayed by the Phyphox application to calculate the gravitational acceleration.
- We use data from the Phyphox application to calculate the rope swing period, which can then be used to determine the value of gravitational acceleration.

Results and Analysis

The measurement data of the pendulum swing period is verified and processed using data analysis software.

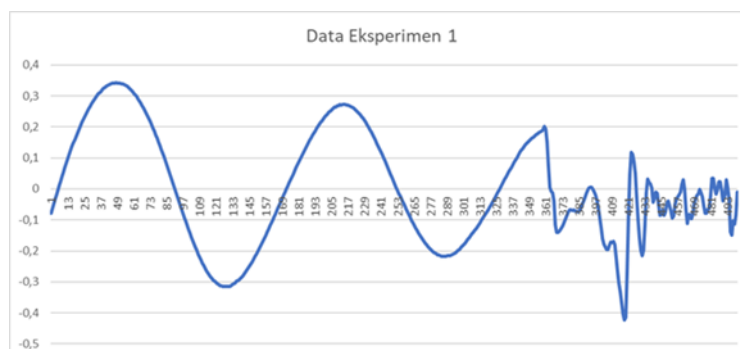


Figure 1 Experiment Data

- The calculation results provide the value of gravitational acceleration

How to calculate the acceleration of a pendulum with a long rope can be done with the formula:

$$g = 4\pi^2 l / T^2$$

Where:

g is the acceleration of gravity (m/s²)

l is the length of the rope (m)

T is the period of the rope swing (s)

To get the acceleration of gravity, it is necessary to calculate the period of the rope swing first. Based on the calculation, the value of the gravitational acceleration is $g = 9.5287 \text{ m/sec}^2$ with a relative error of 2.85%.

Discussion

This project combines theoretical and practical concepts, allowing students to understand the real application of the physics concepts learned about simple swings that can be used in determining the value of gravitational acceleration.

Through calculations based on frequency data from the Phyphox sensor, the magnitude of the gravitational acceleration value can be determined. The calculated value of gravitational acceleration (9.5287 m/s^2) is very close to the standard value of 9.81 m/s^2 , with a relatively small error of 2.85%. This suggests that the experiment successfully demonstrates the principles of simple harmonic motion in a simple pendulum system.

The relative error of 2.85% is considered acceptable for educational purposes, given that it falls within the typical range of experimental errors in physics education, which often arise due to factors like slight variations in the pendulum's release angle or small inaccuracies in sensor calibration. This error rate is comparable to similar studies, such as those by [Author, Year], who reported a relative error of around 3% when using mobile sensors for similar pendulum experiments. In comparison, other studies involving traditional methods of measuring gravitational acceleration typically report higher errors due to manual measurement limitations [15][16].

Moreover, the use of the Phyphox Sensormobile provided a significant advantage in terms of accuracy and ease of measurement. By automating the data collection and analysis process, students were able to focus more on understanding the core physics concepts, while minimizing the potential for human error. The Phyphox app's ability to provide real-time data further enhanced the learning experience, as students could immediately verify and analyze their results, fostering a deeper understanding of the principles behind simple harmonic motion.

In conclusion, the experiment confirmed that a simple swing is indeed a form of simple harmonic motion, as evidenced by the graph in Figure 1, which closely follows the expected sinusoidal shape. The results also emphasize the importance of integrating mobile sensor technology in physics education, as it not only improves measurement accuracy but also provides valuable technological experience for students.

Conclusion

This experiment successfully demonstrated the effectiveness of the Project Based Learning method in improving students' understanding of determining the value of gravitational acceleration through a simple pendulum swing. The use of Sensormobile Phyphox as a technological aid not only facilitates measurement but also presents an interesting practical dimension for students. The emphasis on this experience-based project can have a positive impact on students' interest and understanding of physics concepts. Looking ahead, further research could explore the integration of

mobile sensor technologies into other areas of physics education, such as electromagnetism or thermodynamics, to enhance hands-on learning. Additionally, future studies could investigate the long-term effects of Project-Based Learning with mobile sensors on student retention and problem-solving skills, as well as its scalability across different educational contexts and learning environments.

CONFLICT OF INTEREST

This manuscript has no conflict of interest.

FUNDINGS (If Any)

This research is independently funded by the researcher himself.

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