Using Accelerometer Smartphone Sensor and Phyphox for Friction Experiment in High School

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Abstract. Experiments related to friction in schools are mostly done by direct observation, and it becomes more difficult to determine the value of the coefficients of static and kinetic friction due to the low level of accuracy. This study aims to develop a friction coefficient practicum tool using the accelerometer sensor on a smartphone with the Phyphox application. The research was conducted using the 4D Thiagarajan method (Define, Design, Develop, Disseminate). This tool demonstrates experimental friction on an inclined plane with a variety of surface materials (aluminum, wood, glass, acrylic). The results recorded by Phyphox are spreadsheets of object acceleration data per unit time in x, y, and z coordinate graphs. The sliding plane frame is designed using an Arduino microcontroller which can make it easier for students to automatically form inclined plane angles. This tool has been tested by experts with an average score of 85.25% and has been tested on physics teachers with an average score of 82.5% in the good category. This friction coefficient practicum tool is feasible and can help students understand the concept of friction

1. Introduction

Physics is one of the practical experimental subjects, some of the concepts of physics are formed through mathematical analysis, but in the end the theories that are formed must be tested through experiments [1]. Physics studies the facts that exist then packaged into physical concepts and developed into laws or theories of physics through an experiment [2]. Experimental activities can help students acquire, integrate and build knowledge in a friendly way [3]. Therefore, experimental/laboratory activities have an important role at all levels of education.

Practicum based on mobile application technology (Phyphox) is an application that provides direct access to sensors on smartphones in which there are many simulations that can be used as physics learning media [4]. Phyphox application can be obtained for free and can be downloaded on Google Playstore and Appstore [5]. The use of the functions of the Phyphox application produces valid and reliable data that can be presented to students in real time, without the need to analysed raw data files given in spreadsheet form [6]. Phyphox makes experiments more accessible and expands the tools available to students with simple methods for controlling experiments remotely and with data in the field [5].

With the Phyphox application as a physics experiment application, it is considered capable of solving problems in physics learning. With Phyphox in a smartphone, a teacher does not need a long time to complete the material. Most of the sensors are legible and their measurement data is displayed graphically and equipped with many other suitable innovative features, so Phyphox is very good for use in schools [7]. Thus, smartphones have provided opportunities for new learning perspectives,
including relationships between teachers, students, and learning material [8]. Hence, smartphones can be used as experimental tools in the world of education, including physics [9].

Newton's law is one of the fundamental physics materials in the dynamics of motion. The force of friction is an essential element in motion dynamics. It is essential to teach this topic in physics learning [10]. Friction is one of the interesting topics to study in physics learning. However, the frictional force material is one of the physics materials that is prone to misconceptions, one of which is due to the lack of demonstrations about the frictional force [11]. Many schools conduct experiments related to friction by direct observation, and it becomes more difficult when it is done to determine the value of the coefficient of friction due to the low level of accuracy.

Based on observations, it was found that 41.2% of the 17 teachers only used the lecture learning method in delivering Newton's Law material and 68.8% answered the use of learning media in the frictional force material that was often used, namely power point media. This is due to the lack of complete and inadequate laboratory equipment and materials in schools. By utilizing the Phyphox application on a smartphone, the experimental observation process that has been recorded in the form of a spreadsheet can then be processed more accurately until finally information is obtained in the form of quantities to determine the value of the friction coefficient of objects. Furthermore, by utilizing the Phyphox application in physics learning, it can improve students' analytical skills and creative thinking skills [12].

2. Method
The purpose of this research is to develop a friction coefficient practicum tool on an inclined plane using the accelerometer sensor on a smartphone with the help of the Phyphox application which is feasible as a learning medium. This research is a research and development (R&D) and uses the 4D Thiagarajan method, namely Define, Design, Develop, and Disseminate, with the flow chart in Figure 1.

![Figure 1. Thiagarajan 4D Research Flow](image)

The limitation of this research flow is limited only to the develop stage. The details are as follows:
1. Define stage. A preliminary study starts from analysing the media needed in schools, data are obtained from observations in several schools, this is done to obtain information about the learning process and the availability of practicum equipment in schools.
2. Design stage. The initial design of the practical tool was developed. At this stage, a feasibility test instrument, a product trial instrument was also designed.

3. Development Stage. At this stage, the device framework begins to be developed based on the initial design and development of practicum tools needed by schools.

As for the data collection technique, namely by using a Likert scale test with an assessment weight of (4) strongly agree/ very good, (3) agree/ good, (2) disagree/ less good, (1) strongly disagree/ bad. The following is a presentation of the Likert scale interpretation

| Percentage | Interpretation   |
|------------|-----------------|
| 76 – 100 % | Very Good       |
| 51 – 75 %  | Good            |
| 26 – 50 %  | Less Good       |
| 0 – 25 %   | Bad             |

3. Result and Discussion

The developed media are a practicum tool to determine the coefficient of friction of objects on an inclined plane, which is used for two practical activities, namely determining the coefficient of static and kinetic friction on various kinds of surfaces. The measurement results, use the accelerometer sensor on the smartphone with the help of the Phyphox application.

3.1. Design

The tools and materials needed to design the coefficient of friction practicum tools include a smartphone with the Phyphox application installed, an Arduino microcontroller, a servo motor, a wooden board in an inclined plane frame with a size of 60x20 cm, as shown in Figure 2.

![Figure 2. Tools and Materials, (a) Inclined plane, (b) Phyphox in smartphone](image)

The inclined plane frame is designed using an Arduino microcontroller, IC LM2596, 16x20 LCD and a servo motor that can make it easier for users to automatically form angles with a circuit as shown in Figure 3.
3.2. Experimental data

This experiment uses an iPhone 7 with software version 14.1 in which there is an accelerometer sensor inside. How to use the coefficient of friction practicum on inclined planes, which are:

1) Static coefficient measurement
   The smartphone is placed on a flat surface with an angle of 0°. The glide plane is slowly raised by the object begins to move. The experiment was repeated until 5 data were obtained with different combinations of surface types of materials and bases. The resulting data from Phyphox is then exported for analysis to obtain a static coefficient value.

2) Kinetic coefficient measurement.
   The smartphone is placed with the slope of the glide plane at three variations of angles, namely 30°, 45°, and 60°. The experiment was carried out by changing the type of load and the plane of the slide. The results of the data from Phyphox were then exported, to be analysed to obtain the value of the kinetic coefficient.

The results displayed in the Phyphox application are graphs of acceleration in x, y, and z coordinates per unit of time. The data recorded by Phyphox are in the form of a spreadsheet that can be exported from a smartphone to a laptop in CSV or Microsoft Excel format. The following is an example of the display generated by the Phyphox application:

![Figure 4](image)

**Figure 4.** Display of data recorded by phyphox, (a) Graphical form and average values displayed on a smartphone, (b) Spreadsheet form in Microsoft excel
The results of the data that have been exported to Microsoft Excel are then analyzed to determine the value of the coefficient. The experiment was carried out by the researcher. The data obtained were as follows:

**Table 2.** Example of experimental data on the coefficient of kinetic friction with wood–aluminium at an angle 30°

| Trial of- | \(\theta\) | \(t\) (m.s\(^{-1}\)) | \(a\) (m.s\(^{-2}\)) | \(\mu_k\) |
|----------|-----------|-----------------|-----------------|---------|
| 1        | 30        | 1.23            | 2.76            | 0.252   |
| 2        | 30        | 1.24            | 2.77            | 0.25    |
| 3        | 30        | 1.21            | 2.76            | 0.252   |
| 4        | 30        | 1.24            | 2.77            | 0.25    |
| 5        | 30        | 1.18            | 2.87            | 0.24    |
| Average  | 30        | 1.22            | 2.78            | 0.248   |

The results of the sample measurement data with wood–aluminium surfaces with the help of the *Phyphox* application, the coefficient of kinetic friction at an angle of 30° is 0.248 ± 0.005

**Table 3.** The value of the coefficient of kinetic friction for the entire surface area at an angle 30°

| Plane surface/ Load base | Wood         | Aluminium    | Glass        | Acrylic      |
|--------------------------|--------------|--------------|--------------|--------------|
| Wood                     | 0.345 ± 0.002| 0.323 ± 0.002| 0.254 ± 0.002| 0.285 ± 0.002|
| Aluminium                | 0.248 ± 0.005| 0.280 ± 0.003| 0.204 ± 0.003| 0.242 ± 0.001|
| Glass                    | 0.235 ± 0.003| 0.279 ± 0.003| 0.195 ± 0.002| 0.202 ± 0.002|
| Acrylic                  | 0.283 ± 0.002| 0.266 ± 0.002| 0.215 ± 0.002| 0.250 ± 0.001|

Based on table 3, the value of the coefficient of kinetic friction in various pairs of a material at an angle of 30° tends to be constant. The order of the largest to smallest friction coefficient values is wood-wood > aluminium-wood > acrylic-wood > wood-acrylic > aluminium-aluminium > aluminium-glass > aluminium-acrylic > glass-wood > acrylic-acrylic > wood-aluminium > acrylic-aluminium > wood-glass > glass-acrylic > glass-aluminium > acrylic-glass > glass-glass.

**Table 4.** Example of static friction coefficient experimental data with wood–aluminium.

| Trial of- | \(\theta\) | \(t\) | \(a\) (m.s\(^{-2}\)) | \(\mu_k\) |
|----------|-----------|------|-----------------|---------|
| 1        | 21        | 1.20 | 0.544           | 0.38    |
| 2        | 20        | 1.21 | 0.562           | 0.36    |
| 3        | 21        | 1.18 | 0.543           | 0.38    |
| 4        | 19        | 1.24 | 0.482           | 0.34    |
| 5        | 21        | 1.21 | 0.521           | 0.38    |
| Average  | 20.4      | 1.20 | 0.53            | 0.368   |

An example of experimental data measuring static coefficients with wood-aluminium material obtained the average angle when the object starts to move is 20.4° with a static coefficient of 0.368 ± 0.017.
Table 5. The value of the coefficient of static friction for the entire surface area

| Plane surface/ Load base | Wood       | Aluminium  | Glass      | Acrylic    |
|--------------------------|------------|------------|------------|------------|
| Wood                     | 0.564 ± 0.006 | 0.420 ± 0.008 | 0.518 ± 0.005 | 0.429 ± 0.008 |
| Aluminium                | 0.368 ± 0.017 | 0.371 ± 0.008 | 0.342 ± 0.007 | 0.369 ± 0.083 |
| Glass                    | 0.341 ± 0.006 | 0.304 ± 0.009 | 0.301 ± 0.007 | 0.411 ± 0.008 |
| Acrylic                  | 0.411 ± 0.010 | 0.396 ± 0.005 | 0.358 ± 0.011 | 0.432 ± 0.010 |

The data in the table above shows the value of the coefficient of static friction on various pairs of materials, sorted from the largest to the smallest values, namely, wood-wood > glass-wood > acrylic-acrylic > acrylic-wood > aluminium-wood > acrylic-glass = wood-glass > aluminium-acrylic > aluminium-aluminium > acrylic-aluminium > wood-aluminium > glass-acrylic > glass-aluminium > wood-glass > aluminium-glass > glass-glass.

By comparing the friction coefficient values in table 3 and table 5, for the combination of various pairs of the same material, the static coefficient value has a value that tends to be greater than the kinetic coefficient. On the coefficient of static and kinetic friction, the pairs of materials with the largest and smallest order have the same order. The analytical method using the Phyphox application in experiments to determine the coefficient of static and kinetic friction of various pairs of materials is very helpful for students in understanding the concept of frictional force. In addition, the information provided will be more accurate when compared to direct observation.

The use of sensors on smartphones can be a reference for learning media, particularly in the experimental activities in the classroom. In this research, the kinetic and static friction coefficient between four surfaces can be determined through the acceleration sensor by utilizing the Phyphox application. It is simple, and the devices can be easily found. This experiment is immensely practical, so the teacher and students can carry it out in the classroom without requiring a laboratory [13]. The use of various materials that are easily found can ease learning the experimental activities particularly. Besides, smartphones as the facilities in collecting data can be directly used without any complicated stages [14].

3.3. Implementation

The appropriateness and quality of the friction coefficient practicum tool developed is known through a test by experts. The appropriateness test in this study consisted of a material expert test, a media expert test and a learning expert test. With the results of the feasibility test in table 6.

Table 6. The expert test results

| Expert test of-       | Score  | Interpretation |
|-----------------------|--------|----------------|
| Media                 | 80.4%  | Very Good      |
| Material              | 90.84% | Good           |
| instructional         | 84.5%  | Good           |

Based on the results of the table above, all aspects of the assessment that have been tested by experts are in the very good category with an average score of 85.25%. Furthermore, this practicum tool was tested by 8 physics teachers by giving a questionnaire. With the results of the score in table 7.

Table 7. Teacher test results

| Aspect   | Score | Interpretation |
|----------|-------|----------------|
| Structure| 85.0  | Good           |
| Design   | 80.6  | Good           |
| Concept  | 83.4  | Good           |
| Content  | 84.3  | Good           |
| Interactivity | 79.2 | Good           |
Based on these results, all aspects assessed by the teachers were in the very good category. With a total average in all aspects of 82.5%.

4. Conclusion
Based on the results of the effectiveness test to the teacher, it was found that the use of the Phyphox application on a smartphone was considered effective for learning physics, especially for experimental activities in the classroom so that it helped understanding the frictional force material with a total score of 82.5 in the good category. In addition, experimental activities like this can save time. Learning with Phyphox also provides opportunities for students to actively and directly participate in understanding the material and prove it with real evidence. Through the acceleration value of the sliding object obtained on an inclined plane using various materials, the coefficients of static and kinetic friction on each material can be easily determined. These results can provide further development of the use of light sensors on smartphones, spring systems or fluids for physics experiments and block on inclined planes. Further development in this research can be done by analysing theory analytically.

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