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The Model of Physics Experiments Using Smartphone Sensors in Senior High School 1 Pangkalpinang

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Abstract

The aim of this research is to report the development of a physics experiment model for high schools by utilizing sensors on smartphones as devices for collecting of observing data on physics experiments to increase students' level of understanding. The research method used is research and development. The teacher arranges the physics experiments manual so that students can use it. Retrieval of data in the experiments uses the Research Based Learning (RBL) method so that students have the freedom to be creative in using smartphone sensors. The model is expected to help students in understanding the concepts of physics through experiments using smartphone sensors.

Keywords: model, physics experiment, smartphone sensor

Introduction

Verkasalo, et al. (2010) reported that not all smartphone users maximize the sensor functions found on smartphones. Users only access simple applications related to daily communication and do not involve all sensors. The use of smartphones in physics experiments was first carried out by Müller, et al. (2010) in a smartphone sound experiment on air vacuum tubes, followed by subsequent studies (Voght and Kuhn, 2012, 2013). The two papers triggered subsequent studies on the use of smartphones. Experiments using smartphone sensors are divided into four categories, as follows.

First, research uses sensor hardware installed in the smartphone to obtain certain data. The data are then illustrated in a graphical form for subsequent analysis (Müller, et al., 2010; Voght and Kuhn, 2012, 2013; Taspika, et al., 2018; Klein, et al., 2014; Kuhn and Voght, 2013). Second, research uses certain Android or iPhone applications that are installed on smartphones. The application can record data while displaying data plotting directly on the smartphone screen (Chevrier, et al., 2013; Oprea and Miron, 2014; Forinash and Wisman, 2012; Sans, et al., 2013; Staacks, et al.). Third, research uses cameras and screens on smartphones in which the ability of digital cameras on smartphones can record the movements of objects in physics experiments, so that physical symptoms can be observed (Tornaria, Monteiro, and Marti, 2014). Fourth, physics research combines sensors, cameras, and screens on smartphones with other data such as GPS data, Earth's magnetic pole and other data (Science on Stage, 2021).

The smartphone is affordable and can be bought easily anywhere so students and teachers can use it in physics experiments at school. It is, therefore, necessary to develop a manual for using standard smartphones for physics experiments at school. The teachers and students can gain benefits from it.

Methods

Mobile phones have at least two transducers or sensors namely sound and signal sensors. As the development of smartphone technology is very rapid, the number of sensors used also increases. The latest smartphones have at least 11-12 sensors embedded in the device. The more sophisticated the smartphone specifications, the more sensors are installed in the smartphone.

Figure 1. Number of sensors on a Smartphone (Majumder and Deen, 2019)

As a guide for data retrieval in a physics experiment, teachers must provide physics experiment manuals. The manual can be arranged based on textbooks or other references.

Conventional physics experiments can be arranged based on a diagram shown in Figure 2. Physics experiments based on this diagram fully use physics tools from the laboratory. For physics experiments using smartphone sensors, the manual diagram in Figure 2 must be modified so that it contains steps of identifying sensors within the smartphone that will be used for experiments and calibrating them (Figure 3).

Figure 2. Physics experiment diagram

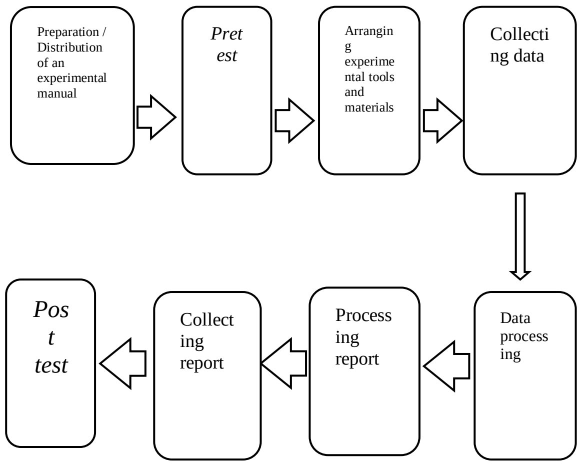
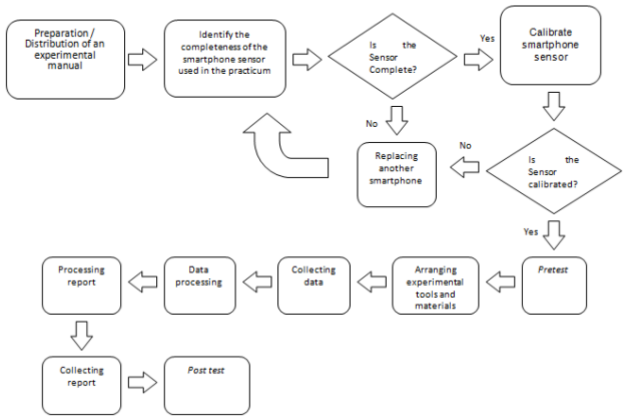


Figure 3. Diagram of physics experiment using smartphone sensor



The study was carried out by testing two types of laboratory manuals on students: the first laboratory manual for ordinary physics labs and the second for the laboratory manual physics involving smartphone sensors.

The level of success and understanding of students can be compared in the two types of laboratory manuals.

The study took data from several sensors on smartphones that were used in two physics experiments. The topics of the experiments were chosen based on the ease of data retrieval using sensors and the order of delivery of material in class. The following topics of the experiments:

a. Oscillatory motion of a pendulum

In this experiment, we use a gyroscope sensor and an accelerometer as the motion sensor. The smartphone is taken as the bob of the pendulum with varied strings. Moving back and forth of the smartphone show the oscillation. Data that appears in the sensor are in the form of changes in the coordinates of the smartphone's position. By using the Phypox pendulum period application, the students see the sinusoidal graphs of the oscillatory motion.

b. Free fall motion (acceleration due to gravity)

We consider objects that experience a free fall motion with a zero initial velocity and a certain height above the Earth's surface. The objects experience a constant gravitational acceleration. The value of gravitational acceleration can be calculated from the travel time of the object during the motion. The microphone sensor on the smartphone can be used to capture sound waves that appear during the objects falling. The time interval of the sound waves is then recorded.

The most important thing in a manual experiment is the instructions for using the application/software used when retrieving data. In this study, the android application used was PHYPHOX developed by RWTH Aachen (Staacks, et al., 2018). This application has several advantages. Students can see graphs of data recorded from the sensor directly on the laptop screen using a wifi hotspot on the condition that the smartphone and laptop are connected to the wifi network. Visible data can be downloaded in the form of graphs or numerical data so students can process and study the data.

A physics experiment guide compiled by the teacher as a researcher is applied in the classroom by students to retrieve data. Experiment guides must be in a standard format, containing information on the specifications of the smartphone used, types of applications, materials, and practical tools as well as the experimental procedures.

The testing of experimental instructions is carried out in two stages according to the number of experiment titles. Before testing students should first read the practical instructions and install the required applications. Data collection for each experiment's title requires 30-35 students.

Results and Discussion

Before starting an experiment using smartphone sensors, students are required to check the availability of sensors on their smartphones and calibrate the sensors that will be applied for the experiment. The existence of sensors in a smartphone can be traced from smartphone specifications or also by installing a certain application that can detect all the sensors. Sensor calibration can be done by installing an application that can calibrate the sensors installed in the smartphone. Some smartphones have facilities embedded in each smartphone that can calibrate a sensor by itself.

The application of Physics sensor-based experiments smartphone methods can be seen from the level of understanding of students. Likewise with the effective use of these methods in physics experiments. To test the level of students' understanding can use the pretest-posttest during physics experiments. This test is also known as the before-after method. The test results using the question instrument show an increase in students' understanding. If using conventional experiments methods the level of understanding achieved is 46%, whereas if using a smartphone sensor-based physics experiments method the student's understanding level becomes 92%.

In addition to the level of understanding of students, we also study the effectiveness of the use of smartphone sensor-based physics experiments methods. Testing uses paired t-test-related methods. The components tested in these experiments are the components contained in the experiment instructions. These components are:

a. Aim

b. Basic theory

c. Tools and Materials

d. Procedure

e. Data retrieval

f. Data processing

g. Graphical depiction

h. Conclusions.

The data analysis shows a significant increase in the level of ease of using smartphone sensor-based practical methods. In conventional physics experiment methods, student respondents showed an average level of ease of 54%. This shows that students have difficulty understanding conventional physics experiment instructions. On the other hand, the results of data analysis on smartphone sensor-based physics experiments showed an average yield of 91%, a 37% greater than the previous method. The calculation of the paired-related t-test obtained a difference value of -11.94, the value of P = 0.00, with group 1 mean (conventional experiment instructions) being 17.21 and group 2 mean (sensor-based experiment instructions) being 29.15. So data analysis is significant and tends to increase. Experiments using a smartphone can be better carried out provided that all the smartphones used by students should be the same type and brand. Accordingly,

1. Students should have the same type and brand of smartphone, or

2. The school provides several smartphones of the same type and brand.

Conclusion

A smartphone sensor-based physics experiment can be carried out by considering the unavailability of measuring instruments and the efficiency of the experiment's data processing or graphical depiction. Physics experiments that are carried out must be integrated with sensors embedded in smartphones. Applications used on smartphones consider the ability of these applications to read data from sensors and the number of sensors available on smartphones.

The principle of using a smartphone sensor in physics experiments is that the sensor can read changes in physical symptoms to be observed. Examples of changes in physics are changes in position, changes in sound frequency, orientation changes and so on. Experiments can be carried out by considering the completeness of the sensor and the suitability of the application with the smartphone.

Experiments instructions as a guide for students in implementing smartphone-based physics experiments are prepared by the teacher by adding the following elements:

a) Sensor type

b) Operating system (Operation System / OS) from a smartphone

c) Sensor calibration warning

d) Types of smartphone applications

e) Instructions for use of the application

After carrying out and analyzing the research data, the following recommendations are generated:

1) Testing methods on other smart devices such as smartwatches and smart bands.

Development of more smartphone-based physics experiments.

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