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The Use of Phyphox Application in Physics Experiments: A Literature Review

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ABSTRACT
Nowadays, the most popular gadget owned by students is a smartphone. The sophistication of smartphones is not only used by students as a communication tool, but also internet browsing, reading e-books, and various other features that can facilitate student activities. In particular, smartphones create conditions for accessing educational programs, scientific materials, and mobile applications for field experiments. Many sensors are integrated in smartphones, thereby adding to the functionality of the smartphone itself. For example, basically every smartphone has an acceleration sensor that is used to determine orientation relative to the acceleration of gravity, a magnetometer to help GPS sensors for navigation, as well as a light sensor and a gyroscope to measure rotational speed. Pressure sensors are also available on some smartphones which can be used as indoor navigation. All of these sensors can be read with the appropriate application and can be used for smartphone-based school experiments, especially in Physics learning. Phyphox is one such sensor reading application that offers many features on it. This study provides reference for the Physics experiments innovation using Phyphox that can also help Physics educational practitioners and researchers to improve the scope and quality of Physics learning programs.

INTRODUCTION

Problems in Physics learning are an important note for Physics teachers because there are still many students who are constrained in understanding the material. In organizing a good Physics learning, Physics teachers face challenges in the form of constructive material. One solution to the problem is to do smartphone-assisted learning to students. The use of smartphones among students is widespread with the development of technology that is very modern. It also encourages that the use of smartphones in all levels Physics learning has increased significantly in past decade [1]. The use of smartphones in Physics learning can support experimental activities by utilizing sensors found on smartphones. Physics experiments using smartphone sensors can provide positive results in the teaching and learning process because these devices are portable and of course students are familiar

with their use. This advantage will be even greater if BYOD (Bring Your Own Devices) is adopted, in which students are allowed to bring and use their own devices, both in class and in school laboratories [2]. Students who use smartphones can easily, efficiently and quickly conduct experiments, collect data in real time that are valid and reliable, also have the ability to review and process data [3].

Smartphone sensors can be used for various Physics experiments. Smartphones are equipped with various internal sensors that record physical data, such as camera, microphone, accelerometer, sensors for magnetic field strength, illumination, or brightness sensors, a gyroscope, GPS receiver, and sometimes even temperature, pressure, and humidity sensors. The original reason why the sensors were installled was not purposes to implement them for Physics experiments. For example, the acceleration sensor is used to determine the device's tilt and to adjust the screen to its orientation. The magnetic field strength sensor is used as a compass to support navigation using smartphone or to inform user about position-specific enviromental data. However, physical data recorded by the internal sensors can be used outside of their actual function with the aid of applications, so that quantitative and qualitative experiments can be carried out in Physics lessons [4].

An important role in study on Physics lessons using smartphone is played by dedicated mobile applications, which have transformed from digital sensors into open platforms that process and analyze experimental data over the years. However, the study shows that the smartphone analysis described from scientific and pedagogical sources is now highly relevant for researching and systematizing the application method as a practical tool for educational study of the Physics lessons. Instrumental innovations have been created by smartphones that contain a collection of sensors and associated software which are suitable for full-scale academic study, especially for remote learning in times of a pandemic or supporting learning innovation in the digital age.

This study provides an overview of posible use and experiments with smartphone sensors in Physics lessons. Smartphone as novel technologies that 21st century students already have in their pockets can inspiring them to do data-driven Physics at school and home by use the sensors in it. The focus of the study is therefore on the "Phyphox" as an application to read out smartphone sensors. This study also describes some of the best experiments to do with Phyphox and go further to suggest how Phyphox might help add interactive minilabs to Physics lessons. Besides, this study includes relevant examples of the Physics projects or experiments which is using Phyphox as a tool to facilitate students in carrying out experimental activities. Physics teachers can use this study as reference in teaching the related topics in Physics learning at school.

METHOD

The research design used was literature review. This research design used to collect data sources on a particular topic [5]. Literature review is a systematic, explicit, and reproducible method. The use of the literature review method is used to identify, evaluate, and synthesize the research results and thoughts of previous researchers. The writing of the review results in this study went through four stages, that is consist of 1) selecting topics to be reviewed, 2) tracing and selecting relevant articles, 3) analyzing and synthesizing articles, and 4) organizing review writing. The collection of literature sources was obtained from various sources through National and International journals by utilizing the academic search engines. The search results that were obtained through the academic search engines use the keywords including Phyphox application, Physics experiments using smartphone, as well as the use of Phyphox application in Physics Experiments. Several articles that matched the keywords were found. These articles have been screened with a range on the year of publication, for the last five years. The articles used were selected and synthesized with high relevance for review.

RESULTS AND DISCUSSIONS

A large quantitative Physics experiments can be done with a smartphone because all sensors can be read by the appropriate software (application). Phyphox (as an acronym for Physical Phone Experiments) is an application to read out the available sensors in a smartphone for experimentation. It was developed by RWTH Aachen. The application is available for free for iOS and Android since September 2016. To support users around the world, Phyphox created and accompanying website at https://phyphox.org, which offers detailed instructions, demonstration videos, and technical information. Until December 2022, Phyphox is already widely used by 3294 devices (submitted by 27020 users) and available in 17 languages. Translators are currently also working on additional languages. The overview of Phyphox current translation efforts can be seen in Figure 1.

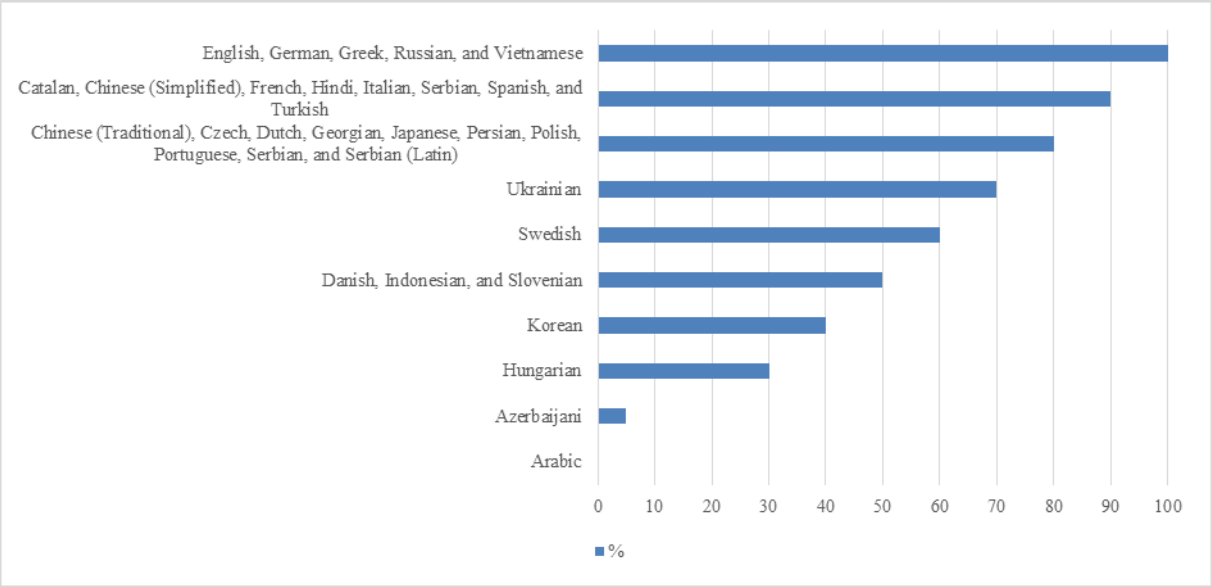

Fig 1. *Overview of Phyphox languages*

Fig 2. *Home screen of the Phyphox application*

Phyphox has been created in order to address two problems in smartphone-based experiments for Physics teaching. Problem 1 when the smartphone itself is inaccessible as it is part of the experimental setup and problem 2 the data is incomprehensible until analyzed on computer. Phyphox adresses problem 1 by adding a simple to use remote access function that allows us to remotely control and observe real-time experimental data from any second device. Problem 2 is addressed by including data analisis within the application [6].

The Phyphox application is highly configurable because it provides the possibility of sharing screenshots, download a csv data file, remote controlled operation from a computer, and acquire data from external sensors. The Phyphox application takes advantage of the sensors that already exist in the smartphone then produces data and/or graphs in real time [7]. This application is very different from other mobile Physics applications because it has many experimental features to use (Figure 2).

This study provides comprehensive information about Phyphox application that have the potential for education in Physics courses in the classroom. With using a smartphone, it is essential to study Physics using the built in sensor of the smartphone for data acquisition to process and interpret it. This aspect of utilizes a smartphone into an indispensable instrument for the teaching of Physics [1].

Some of the best Physics experiments to do with the Phyphox application are described below.

Table 1. The Use of Phyphox in Several Physics Experiments [7]

Physics Subject	Experiments Using Phyphox
Mechanics	Familiar experiments use the combination of internal timers and the smartphone's accelerometer to generate data. Some experiments examples include free fall, centripetal acceleration, speed of an elevator inelastic collisions, and the period of pendulum (spring). Rolling and angular speed experiments work on some pones and can provide experiments on rotational dynamics. Proximity sensor can be used as a photogate timer. GPS monitor that can detect our position can also measure our speed. The magnetometer can be used to make measurements on moving or spinning objects made of ferromagnetic materials.
Sound	The Phyphox application includes many experiments such as sound spectrum, frequency measurements, and decibel vs distance. These can be use by students and teachers for measuring audio frequencies and resonances.
Pressure	The smartphone can detect the change in air pressure from even a meter of height change. The barometer can be used to measure height since pressure changes linearly near Earth's surface.
Electricity and magnetism	Most smartphones contain a magnetometer that can be used as a compass to help us navigate. Since it uses Earth's magnetic field, it must be very sensitive. Thus, it can also be used to detect direct currents. Several experiments using these features are Hall effect to perform Ampere's law and LRC circuit

Many studies related to Physics experiments using Phyphox application have been carried out. Here are the uses Phyphox to read out sensors on smartphones to support Physics learning process, especially in Physics experiments, as presented in Table 2.

Table 2. The Last Four Years Studies Related to the Utilization Phyphox in Physics Experiments

Name Author(s)	Year	Device or Feature	Function
Namchanthra & Puttharugsa [8]	2022	Ambient Light Sensor	Used to measure the value of illuminance.
Vandermarliere [9]	2022	Accelerometer	Used to measure gravity acceleration.
Kaps & Stallmach [10]	2022	Accelerometer	Used in experiment where students may apply the concept of the harmonic oscillations.
Kasper & Vogt [11]	2022		Used to determine the resonance frequencies.
Walid & Umar [12]	2022		Used in free fall motion experiment.
Ilmi, Susila, & Iswanto [13]	2021	Accelerometer	Used in friction coefficient practicum tool on an inclined plane.
Putri, Iswanto, & Marpaung [14]	2021	Audio Scope	Used to assist students in visualizing sound waveforms also seeing differences in sound waveforms before and after interference.
Ludwig-Petsch & Kuhn [15]	2021	Audio Spectrum	Used in audio spectrum experiment.
Fatmawati & Sulisworo [16]	2021	Proximity Sensor, Audio Sensor, and Centripetal Acceleration	Used in kinematics learning tools.
Anni [17]	2021	Acoustic Stopwatch and Accelerometer	Used to determine the gravity acceleration.
Yasaroh, Kuswanto, Ramadhanti, Azalia, & Hestiana [18]	2021	Roll	Used to determine the value of the moment inertia of a hollow cylinder.
Pebralia & Amri [19]	2021		Used in pendulum motion practicum.
Wheatland, Murphy, Naoumenko, van Schijndel, & Katsifis [20]	2021	Gyroscope	Used to analyse gyroscopic data from a mobile phone tossed in the air, including to demonstrate the approximate conservation of rotational kinetic energy and the magnitude of angular momentum.
Pusch, Ubben, Laumann, Heinicke, & Heusler [21]	2021		Used to present the measured data of the power of a solar panel (also using Arduino microcontroller).
Coramik & Urek [22]	2021		Used to determine the kinetic friction coefficient.
Kristiyani, Sesunan, & Wahyudi [23]	2020		Used in guided inquiry-based harmonic vibration experiment.
Kaps & Stallmach [24]	2020	Gyroscope	Used to measure the angular velocity.

Monteiro, Organtini, & Marti [25]	2020	Magnetometer	Used to measure three components of the magnetic field.
Pierrator & Polatoglou [26]	2020	Optical Stopwatch Function (based on Photosensor)	Used to study quantitatively kinematics of the combination Atwood machine and Galileo's inclined plane.
Fatmala, Suyanto, Wahyudi, & Herlina [27]	2020	Accelerometer	Used to study simple pendulum materials.
Weiler & Bewersdorf [28]	2019	Accelerometer	Used in meta-pendulum experiment.
Sahlan, Isafit, & Fayanto [29]	2019		Used to determine the value of centripetal acceleration.
Hikmatiar, Ishafit, & Wahyuni [30]	2019	In(elastic) Collision	Used to determine the coefficient restitution in partially elastic collision.

According to the several Physics experiments using Phyphox that shown in Table 2, Phyphox helps teachers and students to use sensors in smartphones to experiment in class. For example, it is can helps measuring the gravity acceleration using an accelerometer [9] [17]. Another example, Phyphox magnetometer is used to explore magnetic fields created by electric railways then compare them with a simple model and paramaters estimated using easily available information. The left panel of Figure 3 shows the experimental results, while the right panel plots the magnetic field. The agreement between the field measurements and the model is clearly manifested [25].

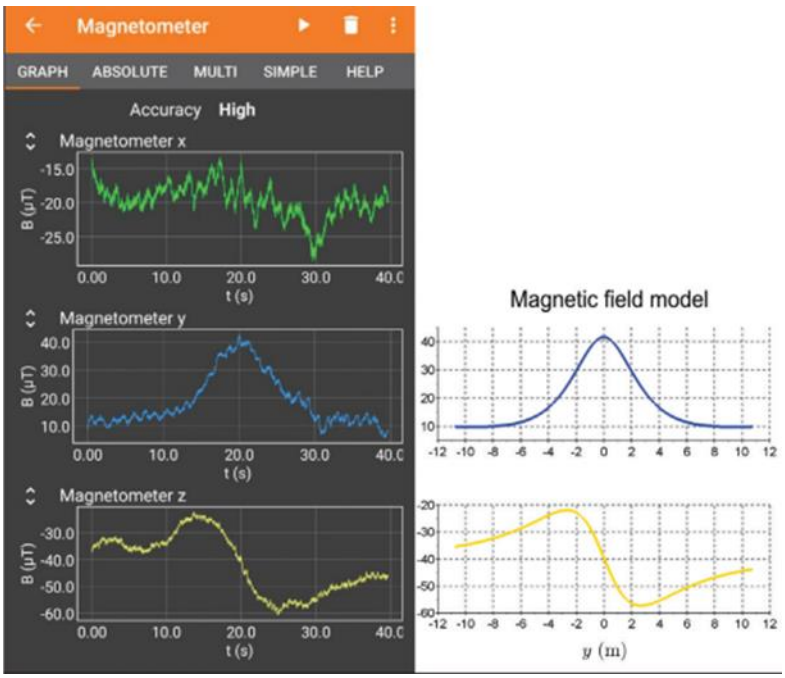

Fig 3. *Comparison between the measurements and the model calculation* [25]

Although several studies did not explain in detail the device or feature of Phyphox used, these studies concluded that the use of Phyphox facilitated Physics experiments. By utilizing Phyphox sensors in Physics learning, teachers and students can do experiments by their own smartphone and low-cost equipment. The Phyphox application on a smartphone can be used in Physics experiment and scientific demonstration in the classroom. It also can be used at home, so it is very helpful without the

need to pay expensive [30]. Studies related to the experiments assisted by Phyphox indicates the data that shown in the Phyphox application is very complete and can be directly processed in Microsoft Excel [31].

Moreover, Phyphox is ideal to improve students' learning abilities. One of the studies shows that the average value of students' creative thinking abilities increased after being given treatment in the form of GIL (Guided Inquiry Learning) assisted Phyphox application [27]. Many students who used the Phyphox application also improved their learning outcomes compared to the students who did not use the Phyphox application [32].

Based on these studies results, it was found that Phyphox as a smartphone sensor application is present a new and useful complement to Physics learning. Student can reach multimedia devices easily, learn about anytime, and anywhere. The Phyphox application can also practice as support in laboratory work carried out by students.

CONCLUSION AND SUGGESTION

Smartphone-based experiments can motivate students as it allows them to explore Physics with their own tools. Phyphox, a free application, makes a variety of Physics experiments more accesible and extends the tools available to students with a simple method to remote control the experiment and with data analysis in the field. Reading the raw data from sensors is good enough to learn data analysis, but understanding the physical experiments background and setting additional requirements for students can enhance their math skills. These requirements can be adjusted using Phyphox by considering the needs of certain Physics classes and learning situations.

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