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The IoT-Based Mathematical Pendulum Real Laboratory Tool

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Abstract. Blended learning is a learning approach that combines face-to-face instruction and online learning. In this case, blended learning will be applied to the mathematical pendulum topic through practical experimentation. The mathematical pendulum experiment is a method used to enhance students understanding of the subject matter. This study aims to develop an IoT-based design for a practical mathematical pendulum tool. The research method is based on Research and Development (R&D). The study results in the development of a practical mathematical pendulum tool and control system through the Blynk application. The data displayed on the Blynk application includes the period (t) and the number of oscillations (n). The accuracy of the infrared sensor FC-51 is tested by comparing it with a stopwatch, resulting in a period data accuracy ranging from 96% to 99%. The period data is then used to calculate the acceleration due to gravity (g) with an accuracy ranging from 93% to 97%.

Keywords: *Mathematical Pendulum Experiments, Internet of Things, Blynk*
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INTRODUCTION

Practical experimentation is a teaching method employed by teachers and instructors to assist students in better comprehending the principles of physics. Generally, practical experiments are conducted in laboratories to provide students and learners with a hands-on experience (Setyaningrum et al., 2013). Typically, practical activities are carried out through a series of steps. Students and learners conduct experiments themselves, accompanied by an instructor or laboratory assistant, in order to personally experience and verify what they have learned or a particular event that has occurred or is occurring. They then observe a process, examine the research object, analyze the data, prove evidence, and draw their own conclusions about the research object, situation, or process related to their subject matter (Kurniawati et al., 2015).

Blended learning is a form of education that combines face-to-face (offline) and online learning methods. It involves integrating traditional in-person instruction with virtual or internet-based learning. Blended learning allows for a flexible and dynamic approach to education, utilizing the benefits of both physical classroom interaction and digital resources. By merging the advantages of in-person teaching and online platforms, blended learning aims to enhance the learning experience and cater to different learning styles and preferences. (Dinning et al., 2015).

Research on mathematical pendulum instruments conducted using a microcontroller as the data processing unit has been carried out by many parties, including a study conducted by Farasdaq (2020) using Arduino UNO and the Infrared Sensor FC-51 to detect of an object (Farasdaq, 2020). The data accuracy error from Farasdaq's device range from 0,2% to 1,3%. The difference between Farasdaq.s research and other researchers lies in the choice of microcontroller used. The researcher used Nodemcu ESP8266, while Farasdaq used the Arduino UNO. The development of the previous research was done by creating a mathematical pendulum laboratory device that can be accessed and controlled online via a smartphone, which was conducted offline for data collection. Simple harmonic motion is an event where a system exhibits a restoring force that is proportional and opposite in direction to its displacement. This motion is considered simple when it occurs in a sinusoidal manner with a single external force acting upon or impacting the system. As a result, simple harmonic motion occurs as long as the system's displacement is not too large (Giancoli, 2014).

The internet of things can be described as a capability an object for transmitting or transmitting data over the network without using the help of a device computer or human. The Internet of Things (IoT) is a form of recent development in internet technology experiencing very rapid developments in the IT field(Information Technology) From the background above, this research was developed, namely the implementation of a learning approach about pendulums with the internet of things

METHODS

The type of research method used is Research and Development (R&D) with the PPE (Planning, Production, Evaluation) development model which contain of three stages: planning, production, and evaluation (Rustandi et al., 2020). The research, testing, and analysis were conducted from February to June 2023. The research location was in the integrated Laboratory of The Physics Study Program, Faculty of Science and Technology, Walisongo State Islamic University. The following are the stages of conducting the research:

1. Literature Review

The stage of the research is conducted by searching for references related to this study. These references serve as a foundation for the initial groundwork in this research, ensuring that the development. Design, and implementation of the study align with the intended objectives.

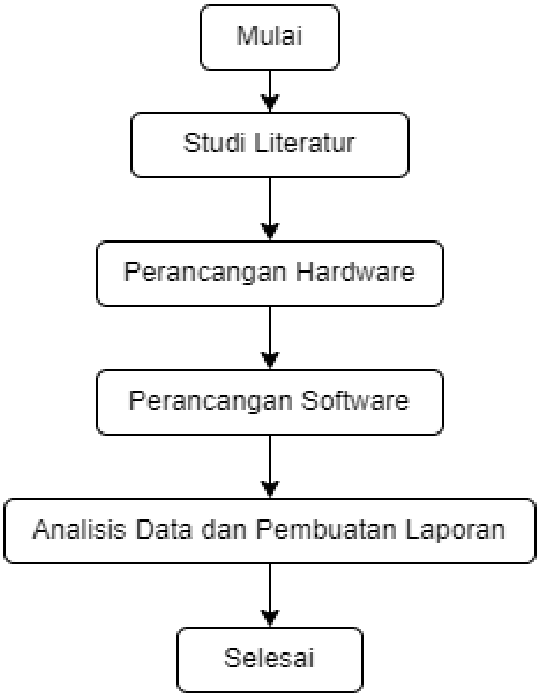

Figure 1 *The Steps of Methods Flowchart*

2. Device Design

At this stage, the hardware design is carried out, which includes the selection of devices and materials, the design of the mathematical pendulum experimental apparatus, the layout of the devices, and the operational flow of the electronic components used, as well as the electric circuitry.

3. Data Analysis and Report Preparation

The final stage involves conducting unit testing on the core components, the infrared sensor, and uploading data from the microcontroller to the application. These tests should be performed as accurately as possible since they will impact the accuracy and success of the mathematical pendulum design. After obtaining the test results, the data is processed, and conclusions are drawn based on the findings. A report summarizing the research findings is then prepared.

Application Design

Blynk is an Internet of Things service provider application that can be downloaded on Android and iOS devices. The usage of the application is relatively easy for beginners. After downloading and installing the application on a smartphone, the next step is to register a Blynk account using an email address. Once registered, the next step is to open a new project and obtain an authentication token that is sent to the email used during account registration. The token is used to authenticate the smartphone with the IoT Serang kota server.

Figure 2 *The Blynk Apps Design*

Device Design

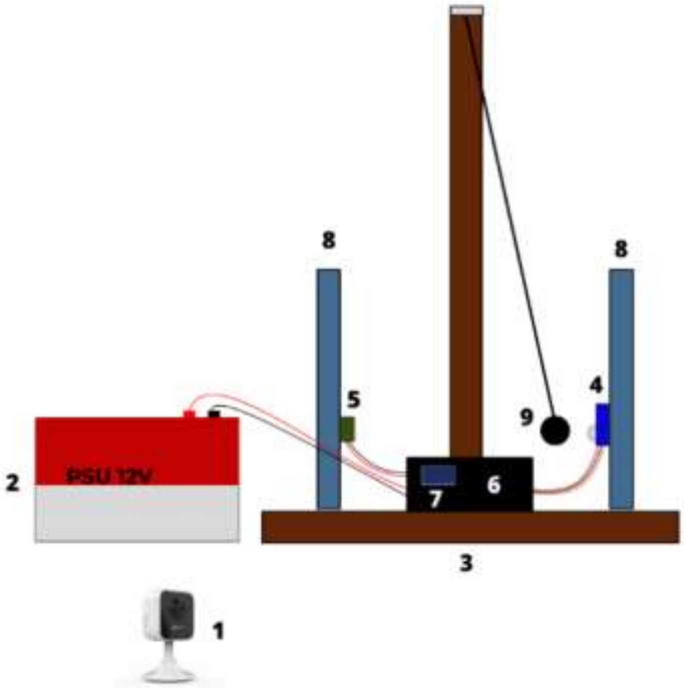

Figure 3 *The Device Design*

The design and construction of the IoT-based mathematical pendulum laboratory device can be seen in Figure 6. The detailed explanation of the tool is describe as follows:

1. The IP Camera is used to monitor the progress of the device through video live streaming.
2. The 12V Power Supply Unit (PSU) serves as the voltage supply the voltage supply for the electromagnet.
3. The static base of the device, made of wood, is used to hold the equipment box and the processing unit device itself. Wood was chosen as the material due to its affordability and ease of modification in terms of shape and dimension for the base.
4. The infrared FC-51 sensor, positioned on the stand, is utilized by the researcher to detect each oscillation of the object with a distance ranging from 1 to 2 cm.
5. Electromagnet to pull the ball object.
6. The box serves as the packaging of the processing unit of the device.
7. The 0.96 inch OLED is used to display the number of oscillations and the period per oscillation.
8. From left to the right, the stand is used to attach the electromagnet and the infrared FC- 51 sensor.

Hardware Design

The design of the IoT-based mathematical pendulum is divided into two parts. The first part is to attract and release the swinging ball made of metal using an electromagnet, and also to detect the pendulum swing using the infrared FC-51 sensor.

The second stage is the operational monitoring of the IoT-based mathematical pendulum device using an IP Camera. The IP Camera used is EZVIZ C1HC, which utilizes the RTSP method to enable the captured images and videos from the camera to be monitored through a media player and the Blynk application.

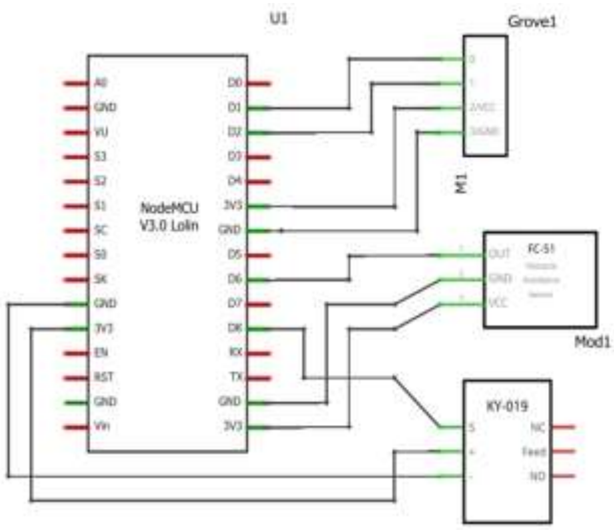

Figure 4 *The Hardware Design*

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Software Design

The software used to program development is Arduino IDE. The choice of this software is because it utilizes the C programming language, which is relatively easy to use for beginners, and because it is open-source software. The data to be obtained in this research are the number of swings (n) data and the period (t) data.

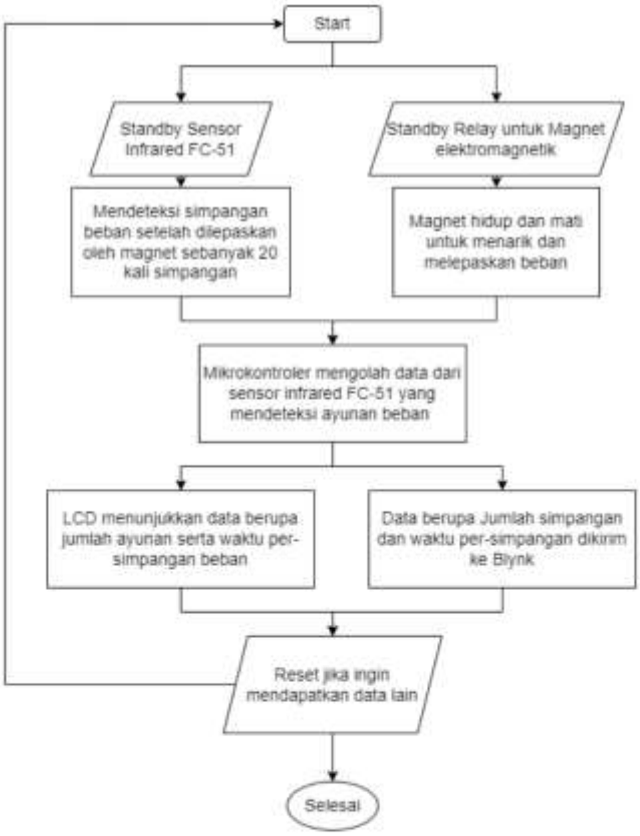

Figure 5 *Flowchart software* mathematic pendulum

Figure 6 *Flowchart IP Camera*

Device Testing

The obtained data is processed to determined the accuracy level of the device. The accuracy and relative errors of the period data (t) in the IoT-based mathematical pendulum laboratory device can be determined using an equation

$$KR = \frac{\Sigma \quad t}{\underline{t}} x100\%$$

$$Ketelitian = 100\% - KR$$

The accuracy and errors of the gravitational acceleration (g) fata in this IoT-based mathematical pendulum laboratory device can be determined using an equation

$$KR = \frac{\Sigma \quad g}{\underline{g}} x100\%$$

$$Ketelitian = 100\% - KR$$

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RESULT AND DISCUSSIONS

The result of unit testing of the device involved measuring the infrared FC-51 sensor, which provided the value of *T*.

Figure 7 Streaming Video Blynk aplication

These sensor measurements resulting the gravitational acceleration values were obtained using a iron ball with a mass of 50 grams and various string length start from 103 cm, 98 cm, 93 cm, 88 cm, and 72 cm.

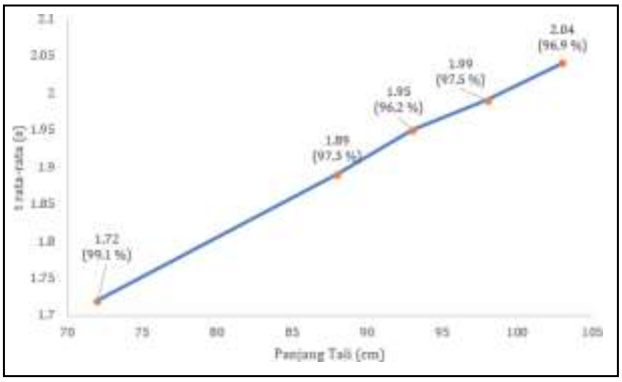

Figure 8 *The Oscillation Period and its Accuracy*

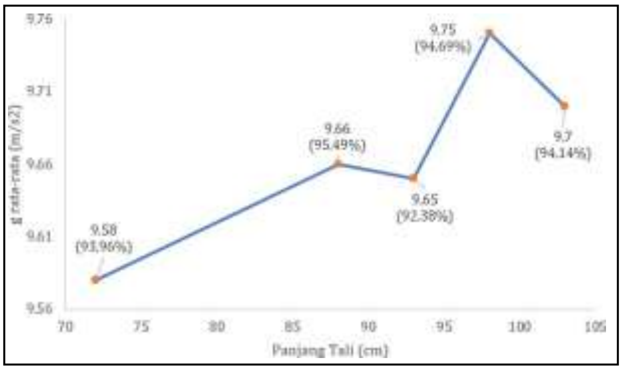

Figure 9 *The Gravity Acceleration and its Accuracy*

According to (Serway & Jewett, 2014), the period and frequency values of a mathematical (simple) pendulum are influenced by the length of the string and gravitational acceleration. The average period values obtained from the given string length and gravitational acceleration are as follows :

$$T = 2\pi\sqrt{\frac{l}{g}}$$

from the equation above, it can be observed that the period of a simple pendulum is directly proportional to the length of the string, indicating that a longer string will result in a longer period of oscillation. On the other hand, the value of gravitational acceleration is nearly constant at approximately 9.78 to 9.8 m/s^2 in most locations on Earth. Consequently, the string length becomes a variable that can be adjusted to obtain different period of oscillation for a simple pendulum.

As shown in the accuracy difference graph in Figure 9, significant variations in the calculated gravitational acceleration can be observed when measuring the oscillation period using five different string lengths. These differences deviate considerably from the universally determined gravitational acceleration value of 9.8 m/s^2. Notably, the variation in string length of 73 cm shows a gravitational acceleration of 9.58 m/s^2, indicating a noticeable from the standard value. The discrepancy is due to the fact that the period of oscillation is not dependent on the mass of the suspended object but rather on length of the string. The period is directly proportional to the string length, resulting in different values of gravitational acceleration (Yanti et al., 2020). For mathematical pendulum experiments (simple pendulum), it is recommended to use a minimum string length of 100 cm, the data results presented above can be used as a standard for mathematical pendulum experiments using string length of 103 cm and 98 cm, as the obtained value of *g* (gravitational acceleration) closely approximates the actual value of gravitational acceleration in the region around the equator, similar to the location where this research was conducted.

CONCLUSIONS

The result on the design and development of the device can be utilized and accessed through an android device using the Blynk apps, which is based on the Internet of Things (IoT). Apps and OLED which includes the number of oscillations (*n*) and the oscillation period (*t*). However, the data for gravitational acceleration (*g*) cannot be displayed in the device in this research due to unstable update rates and limitation in the calculation results, which do not reflect the desire outcomes due to coding difficulties. Based on the data obtained from the device testing, average values of gravitational acceleration were obtained from various string lengths. At a string length of 103 cm, the value of *g* was found to be 9,7 m/s^2 with an accuracy of 94.14%. At a string length of 98 cm, the value of *g* was found to be 9,75 m/s^2 with an accuracy of 94.69%. At a string length of 93 cm, the value of *g* was found to be 9.65 m/s^2 with an accuracy of 92.38%. At a string length of 88 cm, the value of *g* was found to be 9.66 m/s^2 with an accuracy of 95.49%. At a string length of 72 cm, the value of *g* was found to be 9.58 m/s^2 with an accuracy of 93.96%. The accuracy of the calculated *g* values is closely related to the measurement of the oscillation period (*t*) using the infrared FC-51 sensor, with accuracies ranging from 96.2% to 99.1%.

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