Internet of Things (IoT) Based Free Fall Motion Instructions in Physics Subjects for Class X Students

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Abstract—Physics subjects are one of the most difficult materials for students to understand. According to the research that has been done, props are one of the answers to make it easier for students to understand physics lessons. Since most physical materials are directly related to everyday life, props serve as a practical medium to facilitate the learning process. Learning physics concepts is easier to understand by using props which we simulate based on real events. One of the materials in physics class is free-fall motion. In this material, when an object falls from a height and has no initial velocity, its falling velocity is calculated. In this study, we apply the Internet of Things (IoT) to the props of free fall material and by adding Ambrose's concepts namely practice and feedback, so that students can better understand the material of free-fall motion. By implementing IoT, the system can record, read, record, and evaluate the experimental activities performed by users, and users who already have an account can access it online through the website. The system was evaluated based on system functionality and accuracy generated by the system. Based on the test results, it was found that all functions included in the system were 100% working. Based on the three tests performed, the system achieved an average accuracy of 80%.

Keywords: Props; Free-Fall Motion; Intenet of Things (IoT); System Performance; Ambrose.

1. INTRODUCTION

Physics is one of the sciences that study nature and phenomena or natural phenomena and all the interactions they contain [1]. Physics is known as one of the most difficult subjects [2]. In physics, there is a science that studies the motion of bodies in free fall. Freefall is the process by which an object falls from a height with no initial velocity value [3]. To explain more about free fall, teachers often use visual aids to make it easier for students to understand the material [4]. Props are learning media that contain the characteristics of the concepts under study.

Based on Dale's experience in Susilana and Riyana (2007-7), it can be seen that, according to the tests they did, learning experiences through explaining concepts would significantly improve students' memory by up to 90%. In other words, the use of props in the teaching and learning process to help facilitate teachers and students is very effective, as students enthusiastically participate in the experiments that be conducted [5]. Understanding the concepts contained in physics requires a deep understanding that can only be achieved through experience and practice. Therefore, the concepts of practice and feedback are included in Ambrose's concept of the learning body [6]. Students are asked to practice using these props, after experimenting, students give an opinion on the results they obtained in the experiment. Based on this opinion, the students experiment again to address the deficiencies they have gained from the previous experiments. If this can be done, then the stigma contained in the minds of students who suppose physics is difficult can be removed [7].

To make it easier for teachers and students the gain knowledge of the system with free-fall motion props, the concept of automation on the tool will be applied [8]. Therefore the Internet of Things (IoT) will be combined with free-fall motion props to make it automated and join it to different objects through a network [9]. So in this study, we design and implement free-fall motion props by using IoT technology as an assessment medium that can be used by teachers and students [10].

The system was being tested for functionality based on the level of accuracy of the test values obtained by comparing them manually. This is very necessary to adjust the accuracy of the output value on the sensor obtained to be sent to a database website that displays the experimental results obtained so that the results can be observed and downloaded by teachers and students.

The use of technology in education has played an important role in the advancement of the teaching and learning process, especially IoT technology [11]. IoT not only brings changes from traditional to modern teaching models but also brings changes to infrastructure in the world of education [12]. The concept of feedback also plays an important role in the teaching and learning process that utilizes IoT because, with feedback from students, the teaching and learning process in the future can be improved again [12]. Currently, many schools or universities use the smart school system. With this system, schools usually add IoT elements to facilitate teaching and learning activities, for example by using RFID to perform attendance, using an interactive whiteboard, or using the Learning Management System to upload materials and assignments [13].

Research conducted by Ekasari Dian et al [14], aims to create an IoT-based Free Fall Movement tool along with worksheets that can function as a medium for learning physics. The results of the research are Free Fall Motion tools that can count the time when objects are falls, differ the top of falling objects, launch objects automatically to the ground, and can inspect the effect of the mass of objects on the time when objects are falling by utilizing a sound sensor. The developed tools have been tested in design and material. The test results stated that the tools used were very interesting, effortless to use, and very beneficial. Student learning results after the
usage of this tool 100% reach the KKM limit so that the tools developed are very advantageous and appropriate for use as learning media. Research conducted by Kause M. C. et al [7] experimented to measure the value of the acceleration due to gravity using Arduino to determine and visualize the value of object acceleration. The performance test results of the props show that the tool has succeeded in visualizing the process of free-fall motion, measuring the acceleration of Earth’s gravity with an average value of 10.2 m/s², and proving concepts in free-fall motion. Research conducted by Qomariyah N. et al [15] aims to calculate the acceleration values due to gravity using an infrared sensor. At the time of data collection, the sensor has been combined with the existing program on the Arduino Uno which aims to regulate the main function of the props, namely as a timer. The results of three times of taking test data for determining the value of the acceleration of gravity are carried out, the value of the calculation results is close to the value of the theoretical acceleration of gravity. So the conclusion is that this teaching aid can provide a visualization of the phenomenon of free-falling objects. The research was conducted by Infianto Boimau et al [16] who conducted experiments on free fall motion based on a microcontroller as a learning medium to improve conceptual understanding of free-fall motion. The outcomes from the research carried out showed that the experiment had a positive impact because the results showed a moderate value on the points of increasing the score tested with the calculation of N-gain. Research conducted by Aji K. P. et al [13] discusses the Design of an Employee Presence System With RFID Based IoT (Internet of Things) Using NodeMCU ESP8266. So this research can make it easier for the Tourism Office to make attendance systems for employees more effective and efficient and not take up much time. This machine is built-in with the website so that when an employee makes a presence, the information is automatically saved in the website database. Processing the database on the website using MySQL with the PHP programming language. Research conducted by Jati R.K. et al [17] discusses the design and creation of hopscotch with a computerized system that can overcome these boundaries with digital records, facts saved safely, system requirements without difficulty to duplicate, and more correct. Similar to that, research conducted by Shonia S. et al [18] developed a Bag Toss game to develop skills for children to record the data to IoT platform on the internet. Similar to that, research conducted by Wajdi H. et al [19] discusses developing motor skills with the Internet of Things. Research conducted by Sakinah H.R. et al [20] conducted experiments on applying IoT technology to the Lorenz force educating aid (E-Lorentz) and the system has been analyzed primarily based on its functionality parameters, correct statistics studying and suitability of the assessment are the primary parameters. Research conducted by Setiawan M.I. [21] discusses building technology for reading, assessment, and record based on the activities called Kobela.

2. RESEARCH METHODOLOGY

2.1 Research Stages

The research was conducted based on experiments conducted by testing the system that was built. Then the series of research methods in the experiments carried out consisted of Literature Studies, System Design, Experiments, Results from Experiments, and Analysis of Experimental Results. The flowchart in Figure 1. Shows the methodology of the research carried out.

![Flowchart](image)

**Figure 1. Research Method**

The research method is in Figure 1. It is a flow of steps carried out in research, in other words as a sequence of processes from the beginning of the research to the end. In the first process, the focus is on looking for literature studies or previous research related to props and the process of free-fall motion. After conducting a literature study, the next step is to design the tool that is used. At this stage, we discuss what tools be used and the implementation of how the tools work. Furthermore, conducting experiments on the tools that have been designed and then after getting the results of the experiments carried out, system be analyzed and tested on the results obtained based on the parameters that have been determined then draw conclusions based on the experiments that have been carried out.

2.1.1 Study Literature

Study literature describes the research that has been done which is used as a guide for making tools. By collecting research related to the research conducted, it increases the ideas that can be developed on props.
2.1.2 System Design

System Design describes the flow that is carried out to make the props free-fall motion and is explained below:

a. Flowchart Diagram

Figure 2. represents a flowchart on the system when research activities are carried out, then the value of the object is recorded by the sensor and then enters the value into the database. In this study, the user or student was being given questions to work on then after the student gets the answer to the question given, students directly test the answers they get with this free-fall motion prop. After the student drops the object he wants to test, the system will detect whether the object has been successfully read by the sensor or not, if not, the user must drop the object again and if successful, the value will be stored in the NodeMCU and then entered into the database. To find out the value has been entered or not, students compare the value obtained by the system with the answers they calculated themselves. After comparing them and it turns out that the results are correct, students can download the results to save them so that they can be used as a reference for further experiments. If it turns out that the comparison results are different, then students must recalculate the value they get.

![Figure 2. Flowchart Diagram](image)

b. System Architecture

Figure 3. describes the workings of the system that was built complete with the involvement of users of the system. The device sends the values obtained to the online database website and after that, the results can be downloaded by themselves. First of all, students do a manual count by being given a question from the teacher, then students calculate the time it takes for the object to fall from a height using a stopwatch then enter the value obtained into the formula to solve the question, when students have finished solving the questions then the student must log in to the website to view and download the results of the experiments that students did. After students log in to the website, students test the answers they get by running an experiment on free fall props. Students drop an object that is used as an experiment and the object pass through two infrared sensors with the distance between object and sensor is not more than 10 cm. After the second sensor is passed, the NodeMCU displays the value obtained on the LCD monitor and then enters the value into the website database. After the value appears, the student compares the results of the system with the results obtained by the student manually. After doing the comparison, students can download the results as their database so that they are not easily lost if they want to do the next experiment.

![Figure 3. System Architecture](image)
c. Website Design

Website Design is the design of a website database that stores and displays the values of the experiments that have been carried out. In Figure 4, when students want to run the system on the website, they are directed to the Login page to prevent users other than students at the school from opening the score database.

![Figure 4. Login Page](image)

Figure 4. Login Page

Figure 5. shows the Signup page that students fill out to get an account by entering the username they want to use and the password for their account. Figure 5. appears when the user select “Click to Signup” on the options in Figure 4. If the student does not sign up, the student cannot have an account and cannot open the website. Signing up can only be done by students because the users of this website only come from students while the teacher becomes admin by setting up the value database without having to have an account.

![Figure 5. Signup Page](image)

Figure 5. Signup Page

Figure 6. shows the main view of the website which contains the Check Database feature to view the database of the speed values obtained and the Matching Process feature to evaluate the correct or incorrect answers obtained. Figure 6. appears when the user has clicked the Signup button in Figure 5. and when the user clicks the “Check Database” button, it shows the Table of Database Page in Figure 7. but when the user clicks the “Matching Process” button, it shows Matching Process Page in Figure 8.

![Figure 6. Website Page](image)

Figure 6. Website Page

Figure 7. shows the page view to view the database of values obtained from the sensor. On this page, there is also a feature called Excel to download the database to an excel file and there is a feature called PDF to download the database to a pdf file.

![Figure 7. Table of Database Page](image)

Figure 7. Table of Database Page
Figure 8. display the page used for the assessment. If the user has entered a value in that column, the system judge by comparing the answers in the database, if the value falls into the tolerance value category, which is ± 0.5, the system output is True and the system output is False if it does not match the tolerance value.

Figure 8. Matching Proses Page

Figure 9. display a page from the history of the experiments that have been carried out and the user can download the file. Users can access Figure 9. by clicking the “Download Data History” button in Figure 8.

Figure 9. Matching Status Page

Figure 10. displays the database file of the values obtained from the sensor.

Figure 10. Sensor Database Page

Figure 11. displays the database file of the Matching Process that has been carried out.

Figure 11. Matching Status Database
Figure 12 displays the database files of the registered users.

![Database Files](image)

**Figure 12. User Database**

d. Tool Representation

Figure 13.a is a representation of the free fall props along with what components are needed to build this tool from design in Figure 13.b. The picture consists of a 2.2-meter high pole, two infrared sensors that are 2 meters high, the ESP8266 nodeMCU as a microcontroller, and an Arduino LCD.

![Props Free-Fall Motion](image)

**Figure 13.a. Props Free-Fall Motion**

![Design Props Free-Fall Motion](image)

**Figure 13.b. Design Props Free-Fall Motion**

Figure 14 is an arrangement of devices whose functions are explained in Table 1.

![Circuit Block Diagram](image)

**Figure 14. Circuit Block Diagram**

Table 1. Describe the function of the device components that be used in Figure 14.

| Devices                  | Information                                                                 |
|--------------------------|-----------------------------------------------------------------------------|
| NodeMCU ESP8266          | Function as a microcontroller.                                              |
| Analog infrared sensor   | Serves to detect the speed of objects when dropped from the top of the      |
|                          | experimental pole.                                                         |
| Arduino LCD with I2C     | Serves to display the obtained value                                         |
| Test pole                | Functioning as a media base for the experiment.                             |
| Buzzer                   | Serves to detect if the object has passed the infrared sensor.              |

**Table 1. Tool Function**
e. Algorithm

To more easily understand the program, the algorithm on the sensor is explained in Figure 15.

```plaintext
Program Free Fall Motion
Input: Object/Things
Output: Speed value of object/things
Algorithm:
Sensor = 0
Time = 0
if(sensor != 0) then
    Time = sensor
    Time=Time/1000
    speed=gravity*Time
```

Figure 15. Algorithm on the Sensor

2.1.3. Testing

Tests that are done are checking out the system performance and system functionality. System functionality is tested against hardware components owned by the system. The clearer functions of hardware and software are explained in Table 2.

| Component   | Devices                              | Information                                                                 |
|-------------|--------------------------------------|----------------------------------------------------------------------------|
| Hardware    | NodeMCU ESP8266                      | Check whether the microcontroller is functioning properly based on the program and whether or not information can be despatched to the internet. |
| Hardware    | Analog Infrared Sensor               | Check the performance of the sensor in capturing the value of the objects or things. |
| Hardware    | Arduino LCD with I2C                | Check whether the program can display the obtained value on the LCD monitor. |
| Website     | Database                             | Checks whether the website can display the values obtained from the experiment and can perform its functions such as downloading the test results. |

2.1.4. Testing Result

The testing result from Table 2. Was explained in Table 3. about the results from the test and has been described in more detail in section three about Result and Discussion.

| Component   | Devices                              | Results         |
|-------------|--------------------------------------|-----------------|
| Hardware    | NodeMCU                              | Working.        |
| Hardware    | Analog Infrared Sensor               | Working.        |
| Hardware    | Arduino LCD with I2C                 | Working.        |
| Software    | Website Database                     | Working.        |

3. RESULT AND DISCUSSION

This section explains the tests that have been carried out and how the performance of the system.

3.1 System Functionality Test Results

3.1.1 NodeMCU ESP8266

NodeMCU ESP8266 as a microcontroller and functions as the main controller on the system. In Figure 16. NodeMCU ESP8266 shows a blue light which means it is successfully connected to the laptop. Tests have also been carried out to upload programs that be entered into the NodeMCU ESP8266 via Arduino IDE software and have been successfully carried out.
3.1.2 Analog Infrared Sensor

Figure 14 shows the analog infrared sensor that functions to capture the velocity value of the object. This system uses two infrared sensors so the speed of the object starts to be calculated by the system if the object has been released from the first sensor and finishes when it hits the second sensor which has a distance of 2 meters from the first sensor to the second sensor.

3.1.3 Arduino LCD With I2C

Arduino LCD with I2C serves to display the values obtained in each trial session before the data is entered into the database by the system. In Figure 18.a, it can be seen that NodeMCU is successfully connected to the internet with the appearance of information on the LCD monitor while Figure 18.b, it can be seen that the Arduino LCD with I2C has succeeded in bringing up the experimental value.

Figure 16. NodeMCU ESP8266 Testing

Figure 17. Infrared Sensor Testing

Figure 18.a. LCD Display the NodeMCU Connected To Internet
3.2 System Performance Testing Results

The results of the experiments that have been carried out can be seen in Table 3, which shows the value of the first experiment, then Table 4, which shows the value of the second experiment, and Table 5, show the value of the third experiment. In the three tables, the system assesses by comparing the values obtained manually with the values in the database and comparing the values obtained from the sensor with the values in the database. If the difference in value is considered valid or is still included in the difference based on a predetermined tolerance value, the system output a value of 1 or True and if the value is considered invalid, the system output a value of 0 or False. It can be seen in Table 3, the assessment made by the system on the first experiment resulted in three values that were considered invalid by the system resulting in three False states and seven True states for the first try.

Table 3. First Experiment

| No. | Auto | Manual | Status |
|-----|------|--------|--------|
| 1.  | 1    | 1      | TRUE   |
| 2.  | 1    | 1      | TRUE   |
| 3.  | 1    | 0      | FALSE  |
| 4.  | 1    | 1      | TRUE   |
| 5.  | 1    | 1      | TRUE   |
| 6.  | 1    | 1      | TRUE   |
| 7.  | 1    | 1      | TRUE   |
| 8.  | 1    | 0      | FALSE  |
| 9.  | 0    | 1      | FALSE  |
| 10. | 1    | 0      | FALSE  |

Average 70%

In Table 4, the assessment made by the system on the second experiment resulted in two values that were considered invalid by the system resulting in two False states and eight True states for the second experiment.

Table 4. Second Experiment

| No. | Auto | Manual | Status |
|-----|------|--------|--------|
| 1.  | 1    | 1      | TRUE   |
| 2.  | 0    | 1      | FALSE  |
| 3.  | 1    | 1      | TRUE   |
| 4.  | 1    | 1      | TRUE   |
| 5.  | 1    | 1      | TRUE   |
| 6.  | 1    | 0      | FALSE  |
| 7.  | 1    | 1      | TRUE   |
| 8.  | 1    | 1      | TRUE   |
| 9.  | 1    | 1      | TRUE   |
| 10. | 1    | 1      | TRUE   |

Average 80%

It can be seen in Table 5, the assessment made by the system on the first experiment resulted in three values that were considered invalid by the system resulting in three False states and seven True states for the first try.

Table 5. Third Experiment

| No. | Auto | Manual | Status |
|-----|------|--------|--------|
| 1.  | 1    | 1      | TRUE   |
| 2.  | 1    | 1      | TRUE   |
| 3.  | 1    | 1      | TRUE   |
3.3 Accuracy of Experiment

In this experiment, the authors set a tolerance value for the difference that can be accepted, which is 0.5m/s, if the difference in the speed value obtained is above the value of 0.5m/s, the result is invalid. Based on the results obtained in Table 3, it can be seen that the assessments obtained in the first experiment have three invalid values, this is due to the insensitivity of the sensor to objects so that when the object is to be dropped it must be near the sensor and also caused by the time difference when the user dropping objects when the user wants to turn on and off the stopwatch to count manually. Based on experience and errors made in the first experiment, the user corrected the error so that the calculation was more accurate by bringing the object closer to the sensor and equating in more detail the time when the object was dropped with the time when turning the stopwatch on and off. So that gradually better results are obtained which are shown in Table 4, with only two invalid values than in Table 5, with only one invalid value. To see the accuracy results produced by this free-fall motion prop, it can be viewed in Table 3.

| No. | Auto | Manual | Status |
|-----|------|--------|--------|
| 4.  | 1    | 1      | TRUE   |
| 5.  | 1    | 1      | TRUE   |
| 6.  | 1    | 1      | TRUE   |
| 7.  | 1    | 1      | TRUE   |
| 8.  | 1    | 0      | FALSE  |
| 9.  | 1    | 1      | TRUE   |
| 10. | 1    | 1      | TRUE   |

Average: 90%

Based on the results of the experiments carried out, it can be seen in Table 6, that the first experiment conducted on 10 different objects produced an average accuracy value of 70% and increased in the second experiment conducted with the same object in the first experiment which produced an average accuracy of 80% and increased again on the third experiment which produced an average accuracy of 90%.

| Experiments | Number of Trials | Averages |
|-------------|-----------------|----------|
| First       | 10 times        | 70%      |
| Second      | 10 times        | 80%      |
| Third       | 10 times        | 90%      |

4. CONCLUSION

The results obtained after designing and implementing the Internet of Things (IoT)-based free fall props are very good because all functions of the system can run according to what was planned. Based on the results of the experiments carried out also showed good results due to an increase in the accuracy value of the experiment because the user had applied the Ambrose concept in this experiment, namely practice and feedback, so the user had learned what mistakes were made in each experiment and corrected it to get better results. Good. This is evidenced by the results obtained from three trials, the first experiment only getting an average of 70% while the second experiment got an average value of 80% and the third experiment got an average of 90%. From the three experiments that have been carried out, it can be concluded that the average accuracy obtained after doing three experiments is 80%. These results indicate that the tool made can help facilitate the teacher's work in explaining the free-fall motion material because students can try to do this practice at home and students can immediately find out the results they calculated manually based on the questions given are correct or not just by trying it on this tool. and compare the results on the website database of the value of the experiments they did.

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