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Development of Arduino Uno-Based Free Fall Motion Props to Increase Learning Motivation Towards Practicum Results of 11th Grade Students

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Abstract
Research has been conducted on the development of Arduino Uno-based Free Fall Motion (FFM) teaching aids to increase learning motivation towards the results of practicum for 11th grade students of MAN 1 Mataram. This study aims, (1) to design arduino-based teaching aids on free fall motion (FFM) material, (2) to determine the validity level of teaching aids to 3 media experts and 3 material experts, (3) to determine the increase in student learning motivation, (4) to determine the results of student practicum, and (5) to determine the effect of learning motivation on student practicum results. This type of tool development is Research and Development (R&D). the subject model of this research is MAN 1 MATARAM students as many as 35 students. The instrument used was a questionnaire. The development model in this study uses a 3D model. 3D development model (ThreeD). This model is a modification of the Thiagarajan model which includes 4 stages called the 4D (Four-D) model. Based on the research objectives, a student's practicum teaching aid on GJB material was made. Based on the validity test results, the teaching aids are suitable for use as learning media in class 11 MAN 1 Mataram. Furthermore, the results of motivation based on the value before applying FFM props amounted to 51.60% (pretest). While the interpretation after the practicum (posttest) was 90.44% and the N-Gain was 0.46. This means that there are changes in learning activities in students. For the results of student practicum through the satisfaction interval with a very high category of 11 students, a high category of 23 students, a low category of 1 student and very low 0 students. Meanwhile, the correlation of learning motivation to student practicum results shows rcount> table (0.450>0.344) and obtained tcount> table (2.895>2.035). From the truth value of the hypothesis it can be concluded that there is an influence between learning motivation (X) and practicum learning outcomes (Y) on GJB material.

INTRODUCTION

The development of education today requires teachers to be more creative and productive, especially in the learning process. This is in accordance with the concept of national education goals. The objectives of national education become the benchmark for success in the learning process which not only forms good character in humans but also improves quality human resources (Pasaribu, 2017). Quality education depends on the learning methods applied at school. A good method is a method that suits the needs of the science being studied and various disciplines (Wulantri & Ali, 2018). One part of the discipline is physics. The purpose of learning physics is for students to master various concepts and principles of physics to develop knowledge, skills, confident attitudes, so that they can be applied in everyday life (Putra, Widodo, & Jatmiko, 2016).

In general, physics learning is one of the subjects that is usually learned through a mathematical approach, often feared and tends to be disliked by students. That is, physics is only enjoyed by children who have logical mathematical intelligence (Sartika, 2018). Meanwhile, physics requires two understandings at once, namely understanding the concept and its application. Efforts to make students understand physics concepts require effective and efficient learning (Pertiwi and Setyarsih, 2015). The difficulties experienced by students during the learning process are learning abstract concepts, mathematical calculations, understanding material with complex concepts and solving problems. Students are said to be successful in learning physics if they are able to understand concepts, notions, laws, and theories correctly (Pertiwi & Setyarsih, 2015).

Things that are done by teachers must provide new innovations such as the use of learning methods and media that are in accordance with the material being taught. Methods that can be used in physics learning include demonstration and experiment methods (Wulantri & Ali, 2018). This method can foster student motivation through exercises/practicums carried out. The two methods are undeniable that learning tools and media have a considerable role that helps students understand the material (Mujasam, Taufik, Kaleb A., & Alberto Y. T., 2023).

Learning media is a component of the delivery strategy that can be loaded with messages to be conveyed to students, either in the form of people, materials or props. Teaching aids are learning media that make it easier for students to directly see, observe and understand the actual event process. This is in line with the view of Setiawan & Mahmud, (2020) that props are a learning medium which is a form of depiction of the mechanism of action of an object.

The main function of teaching aids is to reduce the abstractness of the concepts given by the teacher so that students are able to capture the meaning of physics learning concepts. In line with what is said that educational aids act as learning stimulants and can foster learning motivation, so that students are not bored in achieving learning goals (Aminoto, Dani, & Yuversa, 2019). In connection with physics teaching aids, it is reinforced by the view of Wijaya, (2015) that the physics learning process using tools or practicum sets makes it easier for students to understand the material, develop student skills and can be used as teaching aids for teachers in explaining concepts. One of the important materials of physics for the development of physics teaching aids is material about free fall motion (FFM). GJB is one form of straight motion of an object that falls from a certain height without initial velocity influenced by the force of gravity. In GJB, the part that can be analyzed using props simulation is the value of gravity, speed and time of falling objects reaching the floor.

Based on the results of interviews and preliminary observations conducted by researchers with Physics Teacher MAN 1 Mataram on the implementation of physics learning especially practicum, it was found that the practicum tools in the laboratory for several physics experiments were still incomplete. Especially for the GJB experiment at school is still very simple. This is shown from the equipment to calculate the travel time of objects using a stopwatch. Where the stopwatch is on when dropping the object and off when the object reaches the floor, meaning only with the help of the human sense of sight manually. Manual experiments like this trigger practicum failures, it could be that pressing the start or stop button on the stopwatch is not simultaneous when dropping objects. In this context, the limitations of practicum tools in the laboratory are still an obstacle that hinders the creation of an effective learning process, as a result the learning process that takes a lot of time has an impact on practicum targets which often cannot all be met so that this can affect student motivation and practicum results in physics learning. One way to overcome these problems is to take advantage of the development of science and technology.

Learning motivation can be interpreted as a driving force to carry out certain learning activities that come from within and also from outside the individual so as to foster enthusiasm in learning (Monika & Adman, 2017). So it can be said that motivation will always foster the intensity of learning efforts for students so that student learning outcomes will increase (Julyanti, 2021). Meanwhile, learning outcomes or practicum are patterns of actions, values, notions, attitudes, appreciation, and skills as a result of interaction in learning. That is, as one of the benchmarks for measuring the success of the learning process. Learning outcomes reflect the learning process which shows the extent to which students, teachers and educational institutions have achieved predetermined educational goals (Safitri, Kosim, & Harjono, 2019).

The lack of availability of practicum tools in the laboratory can be pursued by making physics teaching aids as practicum tools so that the hope will be able to increase student motivation and practical results on GJB material. There are several previous studies that have developed physics teaching aids, including research conducted by Preliana, (2015), this study successfully developed physics teaching aids on environment-based static electricity material by utilizing used materials or items that are easily found around the environment. in line with this research conducted by (Fitriah, Utami, Sabaryati, & Isnaini, 2020), successfully developed physics teaching aids on temperature and heat based on home materials using tools and materials that can be found in the surrounding environment. Another study was conducted by Haisy, Astra, & Handoko, (2015), in which this study successfully developed physics teaching aids on doppler effect material assisted by PC / Computer soundcard technology. In line with this research, research conducted by Karimah, Subali, & Ellianawati, (2019), successfully developed physics teaching aids on doppler effect material assisted by scope V1.40 software applications.

Research that has been conducted by previous researchers still tends to use home materials and computer assistance, none of which apply advances in science and technology. Advances in science and technology have produced a number of electronic devices that support the development of teaching aids such as one of them arduino microcontrollers which can be used as control devices, detector devices (sensors), display devices or LCDs, and actuator devices (Masyruhan, Pratiwi, & Al Hakim, 2020). The combination of arduino and physics teaching aids is expected to create an interactive and interesting learning experience for students.

Based on the description above, this study aims to (1) develop physics teaching aids as practicum tools on GJB material assisted by arduino uno technology, (2) to determine the validity level of teaching aids against 3 media experts and 3 material experts, (3) to determine the increase in student learning motivation, (4) to determine the results of student practicum, and (5) to determine the effect of learning motivation on student practicum results.

METHODS

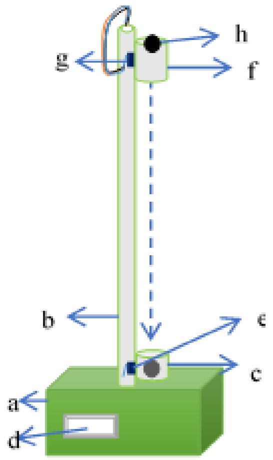
This research is a development research or Research and Development (R&D). The development model in this study uses the 3D model. This model is a modification of the Thiagarajan model which includes 4 stages called the 4D (Four-D) model. The stages of the 3D model include, (1) Define, (2) Design, (3) Develop (Halimah, Irmayanti, & Prastyaningtyas, 2020). Arduino-based free fall motion (FFM) Props Development Research is designed in three stages, namely:

1. Defining stage

In the defining stage, it is carried out to get an overview of the conditions in the basic physics laboratory specifically in the practicum of free fall motion material (GJB). Seeing the limitations in the existing practicum tools, therefore a tool is made that can fulfill the shortcomings of existing tools in the form of adding an infrared sensor to determine the amount of time the object travels while adding a display of the value of gravity and speed to the time the object falls to the floor. At this stage also explored about GJB material through these quantities. Furthermore, the measurement results will be displayed on the Arduino Uno I2C LCD.

2. Design stage

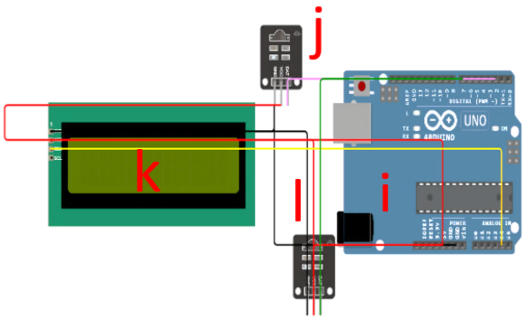
At this stage, the design of arduino-based props is carried out. The general form of the Free Fall Motion props developed is presented in Figure 1.



Description:

a. The anvil box functions as a support and storage for the arduino Uno mechanic.
b. Support Pole serves as a pole for infrared sensors and the height of falling objects
c. Pipe 3 Inc 5 cm long serves as a place for the 2nd infared sensor
d. I2C LCD serves as a monitor of the results of object speed, time and gravity
e. The 2nd infrared sensor serves to detect the final time
f. Pipe 3 Inc 10 cm long serves as a place for infrared sensor 1
g. Infrared sensor 1 serves to detect the initial time
h. Object mass

Figure 1. Schematic of the Free Fall Motion trainer



Description:

i. Arduino Uno
j. 2 Infrared Sensors
k. LCD I2C8j
l. Jumper Cable

Figure 2. Schematic of the Props Set.

The design is carried out by collecting tools and materials used for the process of making props, namely (1) Pipe 3 Inc. functioning as in the description of figure c (2) Support pole / stainless aluminum 1 inch long 70 cm (3) Masa objects / ping pong balls (4) 3 mm plywood as a foundation box, arduino hardware technology components, namely 1 arduino uno, 2 infrared sensors, jumper cables, USB cables and 9 volt battery boxes (6) Supporting tools such as cutting tools, hot glue, rulers, markers, nails, and color pencils. Next, make a schematic of the arduino component design using the help of Wokwi software as shown in Figure 2.

3. Development stage

At the development stage, the validation test of the practicum tool and the practicality test of the practicum tool were carried out.

a) Media and material expert validation

The validation test was carried out by experts in practicum media experts, namely 2 lecturers of physics education FKIP UMMAT and 1 Physics Teacher MAN 2 Mataram. Furthermore, material experts were carried out by 2 lecturers of physics education FKIP UMMAT and 1 Physics Teacher MAN 2 Mataram. Validation activities are carried out in the form of filling out the validation sheet for the GJB practicum tool. At the trial stage, data was collected using an open assessment questionnaire to provide criticism and suggestions or input for improving the media developed from the expert validator.

The results of this descriptive analysis are used to determine the practicality and accuracy of the product of the development of learning media for grade 11 students of MAN 2 Mataram. Data from the expert team validation results using the percentage formula. The assessment scores used are: (1) very invalid (2) invalid (3) valid (4) very valid. From the results of the validity test collected then tabulated. The tabulated results of each score were searched for percentages with equation (1).

$$P(\%) = \frac{score\ obtained}{ideal\ score} \times 100\% \quad (1)$$

The benchmarks used to interpret the percentage of expert team validation results are in accordance with the 4 scales/categories on the Likert scale numbers as in Table 1.

Table 1. Percentage of validity categories of practicum tools

Percentage (%)	Figures	Description
81-100	4	Very Valid
63-81	3	Valid
44-63	2	Not Valid
25-44	1	Very Invalid

(Source: (Arikunto, 2018)

b) Practicality test ptaktikum tool

After the validity test, the next step is the practicality test. Practicality test as many as 35 11th grade students at MAN 2 Mataram. The test carried out is to see the response to student motivation to learn and the results of the parktikum. Calculation of the percentage of learning motivation using equation (2).

$$\% = \left(\frac{n}{N}\right) x100\% \quad (2)$$

with, n is the number of scores obtained and N is the maximum number of scores. The criteria for learning motivation are interpreted in the form of categorizing the achievement of values referring to the score range.

Furthermore, to calculate the magnitude of the increase in student learning motivation or gain normality can use equation (3)

$$gain = \frac{S_{post} - S_{pre}}{100 - S_{pre}} \quad (3)$$

with, Spre is the initial score (taken from the average score) and Spost is the final score (taken from the average score). The data from the calculation of the pre- and post-student motivation questionnaire tabulations will then be interpreted using standardized gain as in Table 2 (Hake, 2002).

Table 2. Standardized gain index values

Standardized gain value	Description
≥ 0,7	High
0,7 ≥ g ≥ 0,3	Medium
≤ 0,3	Low

To see the learning outcomes / practicum of grade 11 students refers to the frequency value of the range of values obtained by students when responding to 18 question items on the practicum results questionnaire. The categories and ranges of practical results are presented in Table 3.

Table 3. Interval value of practicum results

Category	Interval	% interval
Very High	58,50-72,00	≥81%
High	45,00-57,50	62-80%
Low	32,50-44,00	43-61%
Very Low	18,00-30,50	≤42%

Meanwhile, to determine the effect of student learning motivation on practicum results can be seen from 2 X variables, namely student learning motivation and Y variable, namely practicum results. For the correlation, the research hypothesis is determined, namely Ho = there is no influence between learning motivation and practicum learning outcomes and Hi = there is an influence between learning motivation and practicum learning outcomes. The hypothesis used is H_o: ρ≤0 or H_i: ρ>0. After that, compare the difference in the value of r_count with r_table in equation (4).

$$r_{xy} = \frac{n\sum X_i Y_i - (\sum X_i).(\sum Y_i)}{\sqrt{\{n\sum X_i{}^2 - (\sum X_i)^2\}.\{n.\sum Y_i{}^2 - (\sum Y_i)^2\}}} \quad (4)$$

Apart from being consulted with the r_table, testing the correlation hypothesis can also use the t distribution table, by transforming r_xy and t using equation (5).

$$t_{hitung} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}. \quad (5)$$

with, t is the t_count value, r is the correlation coefficient of the t_count result and n is the number of responses.

RESULTS AND DISCUSSION

Definition Stage

In the first stage, literature analysis is carried out consisting of concepts and reference sources and collecting tools and materials used for the design stage. Based on the literature and sources of information, the development of arduino-based FFM practicum aids will be carried out. The props to be developed include the arduino work system on the I2C LCD display including the value of gravity, speed and travel time of objects reaching the floor.

The value of travel time is calculated by utilizing objects/balls that pass through infrared sensor 1 and reach the last point on infared sensor 2. Furthermore, the travel time value is grouped into calculations of object speed against time and connects the gravity value. 3 The value is connected to the arduino uno software program. So, the use of arduino-based FFM props is more interesting, efficient and practical in accordance with technological developments. The arduino software program is shown as in Figure 3.

```
#include <LiquidCrystal_I2C.h>
// set max pixel
const int col = 16;
const int row = 2;
const int IR_Sensor1=2;
const int IR_Sensor2=7;
// initialisasi posisi awal text
int position = 0;
// pemanggilan library lcd
LiquidCrystal_I2C lcd(0x27, col,
row);
double startMillis;
double endMillis;
double free_fall_time;
double h = 0.60;
double g,v;
int activate=0;

void setup() {
  // initialisi awal library
lcd_i2c
  lcd.begin(16, 2);
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("TTG P.Fisika");
  lcd.setCursor(0, 1);
  lcd.print("FKIP UMMAT");
  lcd.begin(16, 2);

  //Pin 2 koneksi ke LCD
pinMode(IR_Sensor1,INPUT);
pinMode(IR_Sensor2,INPUT);
// initialize the LCD
lcd.begin(16, 2);
lcd.setCursor(0, 0);
lcd.print("T:");
lcd.setCursor(8, 0);
lcd.print("V:");
lcd.setCursor(0, 1);
lcd.print("G:");
}

void loop() {
if(digitalRead(IR_Sensor1)==LOW)
{
//lcd.clear();
startMillis = millis();
activate=0;
}
if(digitalRead(IR_Sensor2)==LOW)
if (activate==0){
{
endMillis = millis();
free_fall_time = (endMillis-
startMillis)/1000;
lcd.setCursor(2, 0);
lcd.print(free_fall_time);
lcd.setCursor(6, 0);
lcd.print("s");
g = 2*h/pow(free_fall_time, 2);
v = g*free_fall_time;

lcd.setCursor(10, 0);
lcd.print(v);
lcd.setCursor(13, 0);
lcd.print("m/s");
lcd.setCursor(2, 1);
lcd.print(g);
lcd.setCursor(5, 1);
lcd.print("m/s2");

activate=1;
}
}
}
```

Figure 3: FFM trainer software program

Design Stage

arduino-based FFM props by utilizing arduino components and infrared sensors designed in this study were conducted in class 11 at MAN 1 Mataram school as many as 35 students. At this stage, it starts from collecting materials for making props and electronic components of arduino. After all is collected, the design of the tool is carried out.

The first step describes the assembly scheme of the props as in Figure 1. After the big scheme has been completed, the next step describes the simulation of the arduino scheme as in Figure 2. The two schemes in Figures 1 and 2 are then combined into 1 place, the arduino mechanic as in Figure 2 is stored in the grounding box as in the description of Figure 4.7. For the final results of the props are displayed as in Figure 4.

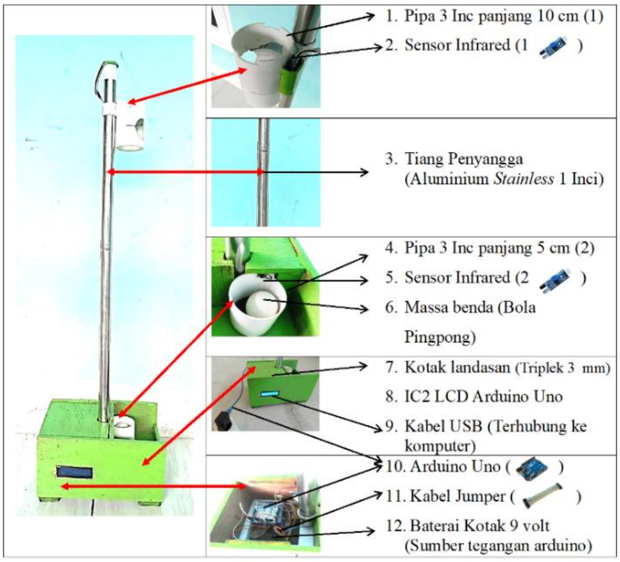


Figure 4. Shape of arduino-based free fall motion (FFM) trainer

Development Phase

a) Product Validation Test

The product validation stage is carried out with media experts and material content experts. Validation is done by taking questionnaire data conducted by 6 people considered representative and experienced in teaching. For media experts, namely 2 lecturers of physics education FKIP UMMAT and 1 physics teacher MAN 2 Mataram. Likewise, material experts are 2 lecturers of physics education FKIP uman and 1 physics teacher MAN 2 Mataram.

The response questionnaire used for media validation contains 1 to 18 question items. The percentage value of product trials conducted by media experts is shown in table 4.

Table 4. Level of validation by media experts

No	Validator	Percentage	Description
1	Validasi I	75,00%	Valid
2	Validasi II	92,20%	Very Valid
3	Validasi III	84,72%	Very Valid

Based on the table 4, validation expert 1 data can be said that the level of validity of learning media using Arduino-based FFM props that have been developed has a valid level of validity. This is evidenced by the number of questionnaire statement scores on items 1-18 given by validators with a validity percentage of 75%. However, according to the media design expert, the researcher still revises the place where the object / ball falls to make it bigger and does not need to use a paralon and also the placement of the infrared sensor is placed at the bottom, so that the ball falls directly into the value and does not need to wait for the ball to enter the paralon.

For the 2nd validation, it gave a response with a very valid level of validity. This is evidenced in the validity percentage of 84.72%. The second media expert validator did not provide revision comments. Meanwhile, the 3rd validator gave a response with the acquisition of a validity percentage of 84.72%. According to the expert, the researcher must revise the sensor placement so that it becomes a perfect learning media.

Furthermore, the product trial assessment was carried out by 3 material expert validators with each question item 18 numbers. Data on the results of product trials conducted by material experts are shown in table 5.

Table 5. Material expert validation level

No	Validator	Percentage	Descriotion
1	Validasi I	86,11%	Very Valid
2	Validasi II	94,44%	Very Valid
3	Validasi III	84,72%	Very Valid

Assessment of product trials conducted by material content experts 1 on physics learning GJB material contained in table 5 can be presented the level of validity of learning media using Arduino-based FFM props that have been developed shows a very valid level of validity. This is evidenced by the questionnaire given by the validator with a validity percentage of 86.11%. According to expert 1, the content of the research material is recommended to add an output display of the amount of energy.

Furthermore, the assessment of the 2nd validator filled in through a questionnaire provided by the researcher shows a very valid level of validity with a validity percentage of 94.44%. According to the second material expert, the researcher gave advice related to the props support poles made more flexible to measure the height of the fall of objects. Meanwhile, validator 3 gave a response showing a very valid level of validity with a total percentage of validity of 84.72%. The suggestions in the questionnaire refer to the placement of infrared sensors on the pipe that can inhibit the motion of free falling objects.

b) Product Trial

The limited trial was conducted on 35 11th grade students of MAN 2 Mataram. With a total of 35 people. The first trial was learning motivation. The use of samples is carried out data collection using sample techniques Before Learning (pree test) and After Learning (Post test). This is done to determine the increase in learning motivation through the N-Gain test (Azwar, 2015). The percentage interpretation of the achievement of the learning motivation questionnaire before learning (pree test) was 51.60%. While the percentage of interpretation of the questionnaire achievement of learning motivation after learning (post test) amounted to 90.44%. Next, calculate the amount of increase in student learning motivation or gain normality. The results of the calculation of the motivation questionnaire before and after are interpreted using the standard gain (Hake, 1998). Based on the results of the N-Gain test calculation, the standard gain index value is 0.46 in the medium category.

Furthermore, to see the results of the practicum through the success rate of students in following the demo or practicum process of the arduino-based FFM tool as many as 35 students with 18 question items. Obtained a data range of 54 and an iteval value of 13.50. Furthermore, the interval and frequency results of the observation and ability to follow the learning process are displayed in table 6.

Table 6 : Interval and frequency data

Category	Interval	% interval	Frequency
Very High	58,50-72,00	≥81%	20
High	45,00-57,50	62-80%	14
Low	31,50-44,00	43-61%	1
Very Low	18,00-30,50	≤42%	0

Table 6 shows the level of observation of experiments or testing of practical equipment there are results of satisfaction with a very high category of 11 students. For the high category, 23 students, while the low category is 1 student and very low 0 students. Therefore it can be concluded that the level of satisfaction through observation of practical activities is very high.

For the test results of the effect of learning motivation on practicum results. Testing uses variable X, namely student learning motivation and variable Y, namely practicum results. For the correlation, the research hypothesis is determined, namely Ho = there is no influence between learning motivation and student practicum results and Hi = there is an influence between learning motivation and student practicum results. The hypothesis used is by accepting or rejecting either Ho or Hi, namely H_o: $\rho \leq 0$ or H_i: $\rho > 0$. To calculate these 2 variables, it is necessary to analyze the value of the correlation level using the produck moment equation rxy (4). The rxy value obtained from the calculation results using the r-produck moment table with a deviation of freedom (dk = n-2) and correlation at α = 0.05. The value of dk = 35-2 = 33, obtained the value of r_{table} = 0.344. Because rcount> table (0.450>0.344) means Ho is rejected. So, it can be concluded that there is an influence between learning motivation (X) and practicum learning outcomes (Y) on GJB material. In addition to the calculation of rxy with rtab testing the correlation hypothesis, it is strengthened by the tcount test by transforming rxy to tcount using equation (5). For the t distribution table at α = 0.05 and dk = 35-2 = 33, the t_{table} value = 2.035 is obtained. From the calculation, the value of tcount> ttable is obtained (2.895> 2.035). From the value of the truth of the hypothesis it can be concluded that the motivation of students to learn in physics subjects GJB greatly affects the results.

CONCLUSION

The conclusion of this development research is that a Free Fall Motion experimental tool is produced that can measure the time of falling objects automatically, can vary the height of falling objects, release falling objects automatically, and can investigate the effect of object mass on the time of falling objects as learning media that has been tested by design experts and material experts with feasible quality and in accordance with theory, and has been tested to users with quality: very interesting, easy to use, and very useful for motivating students and used in practicum according to users.

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