Jurnal Pendidikan Fisika dan Keilmuan (JPFK)
Vol. 7, No 2., September 2021, pp. 108-129
P-ISSN: 2549-4996, E-ISSN: 2548-5806, DOI: http://doi.org/10.25273/jpfk.v7i2.9952

Development of Potential Energy Props Based on Arduino Uno Microcontroller to Improve Student achievement

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Abstrak

Penelitian ini bertujuan untuk mengetahui kelayakan pengembangan alat peraga energi potensial berbasis mikrokontroler arduino uno berdasarkan penilaian ahli media dan ahli materi, keakurasian alat, serta mengetahui peningkatan prestasi belajar siswa. Mikrokontroler arduino uno yang dikembangkan berbantuan sensor ultrasonik dan sensor *load cell.* Prestasi belajar siswa pada penelitian ini mencakup kognetif, afektif dan psikomotorik. Model yang digunakan dalam penelitian adalah model ADDIE yang terdiri atas 4 tahapan yaitu *analysis* (analisis), *design* (perancangan), *development* (pengembangan), *implementation* (penerapan), dan *evaluation* (evaluasi). Berdasarkan analisis data yang dilakukan dapat disimpulkan bahwa validasi alat peraga pembelajaran fisika berbasis mikrokontroler arduino uno oleh dua orang ahli media diperoleh rerata skor 95% dengan kategori "sangat layak" dan oleh dua validator ahli materi diperoleh rerata persentase 95,3% dengan kategori "sangat layak", Keakurasian alat peraga pembelajaran fisika berbasis mikrokontroler arduino uno Untuk tingkat kepercayaan dalam pengukuran diperoleh hasil sebesar 99,14% dengan tingkat ketelitian sebesar 0,86%. peningkatan rerata prestasi belajar siswa pada ranah kognetif sebesar 14,8%, ranah afektif 8%, dan ranah psikomotorik 18,3%. Dengan demikian alat peraga energi potensial berbasis mikrokontroler arduino uno layak digunakan sebagai media pembelajaran di sekolah dan mampu meningkatkan prestasi belajar siswa.

Kata Kunci: Alat peraga,Energi otensial, ikrokontroler, arduino uno, prestasi belajar

Abstract

This study aims to determine the feasibility of developing potential energy teaching aids based on the Arduino Uno microcontroller based on the assessment of media experts and material experts, the accuracy of the tool, as well as knowing the improvement of student achievement. The Arduino Uno microcontroller was developed with the help of ultrasonic sensors and load cell sensors. Student achievement in this study includes cognitive, affective, and psychomotor. The model used in this study is the ADDIE model which consists of 4 stages, namely analysis, design, development, implementation, and evaluation. Based on the data analysis, it can be concluded that the validation of the Arduino Uno microcontroller-based physics learning teaching aids by two media experts obtained an average score of 95% in the "very feasible" category, and by two material expert validators obtained an average percentage of 95.3% with the "very good" category. feasible", Accuracy of teaching aids physics based on Arduino Uno microcontroller. For the level of confidence in the measurement, the results obtained are 99.14% with an accuracy level of 0.86%. the average increase in student achievement in the cognitive domain is 14.8%, the affective domain is 8%, and the psychomotor domain is 18.3%. Thus, potential energy props based on the Arduino Uno microcontroller are feasible to be used as learning media in schools and can improve student achievement.

***Keywords**:* Props, potential energy, microcontroller, Arduino Uno, learning achievement

How to Cite: M Matsun., B Boisandi., S Ira Nofita., H Soka., P Adi. (2022). Development of Potential Energy Props Based on Arduino Uno Microcontroller to Improve Student achievement. *Jurnal Pendidikan Fisika dan Keilmuan (JPFK)*, 7(2), 108-129. doi:http://doi.org/10.25273/jpfk.v7i2.9952

Received August 11, 2021; Revised August 25, 2021; Accepted September 7, 2021

INTRODUCTIONS

Learning physics as part of the science family in the learning process is directly related to how to find out about natural events systematically and empirically. Students are trained to think critically through observation, experimentation, problem-solving, hypothesis testing, drawing conclusions, and predictions to find their knowledge. Students must find useful scientific knowledge based on real experience through practical learning carried out (Rizky et al., 2021). This requires teachers as facilitators to be more creative and innovative in the process of delivering physics learning (Ma et al., 2012).

One of the efforts that can be made to create an interesting and fun physics learning atmosphere is that educators or teachers as facilitators can use learning media in the form of teaching aids. (Lesmana, 2020). The use of learning media in the form of teaching aids is highly recommended because by utilizing appropriate teaching aids, physics learning will be more effective by directly demonstrating and conducting experiments. In addition, by using teaching aids, learning physics which is considered by students as a complicated subject, will become easier to understand, fun for students, and teachers can be more creative in delivering subject matter. (Muchlis et al., 2018). The use of teaching media in the form of teaching aids in the learning process can trigger new desires and interests and can motivate students in learning (Pada et al., 2020).

The use of teaching aids can increase students' learning motivation. High student learning motivation will affect the learning outcomes achieved (Qudsyi et al., 2006). The same is said (Bansal, T., and Joshi, 2014) who said that motivation had a big influence on learning activities. Students who are interested in a subject will study it seriously because there is an attraction for them. Therefore, the existence of teaching aids as a supporting media in the learning process is deemed necessary and very important to be able to grow and develop student learning motivation.

The process of implementing physics learning is currently still emphasizing the use of conventional learning methods, namely lectures assisted by presentation media which are considered to be less effective, causing a lack of student involvement in the learning process (Hikmah et al., 2017) The use of the lecture method only makes students accept the concept of the material being studied without ever proving the concept directly. It is as if students are considered to have the same mastery of the material as the teacher. Teachers always dominate the learning process to achieve learning targets. Physics learning that is carried out is still applying conventional learning methods, namely media-assisted lectures in the form of power points and textbooks which are still not able to attract interest and increase student learning motivation. The use of learning media in the form of teaching aids is not carried out due to the limitations of teaching aids in the laboratory. The involvement of students to be active in the learning process is also less due to minimal use of learning media that is interactive and fun for students such as the use of teaching aids.

Technological advances in the current era of the industrial revolution 4.0 have brought changes to learning tools that work manually starting to be developed with digital techniques such as digital scales, digital stopwatches, digital multimeters, and many more. These changes are made to facilitate data reading and minimize data reading errors caused by human error. One application of technological advances in the era of the industrial revolution 4.0 is the use of the Arduino Uno microcontroller as a technology-based tool that can be integrated with

1 control system, especially in the use of digital technology. Arduino is one of the newest types of controller components from the microcontroller family with a programming language using the C language. With the help of Arduino libraries, it can be used to develop interactive systems that accept input from various sensors or switches by controlling the work of the tool according to the wishes of the maker. Another advantage that Arduino has is low power, so its use is suitable for use as a control system in the manufacture of physics teaching aids in high school (Waluyo et al., 2021). Referring to the problems obtained from the interviews, the researchers want to develop physics learning media in the form of teaching aids that can be integrated into a single control system. The teaching aids that will be developed are based on the use of the sensor-assisted Arduino Uno microcontroller. The topic of discussion that will be used by researchers as a theoretical study and guide to the development of teaching aids is mechanical energy.

The Arduino Uno microcontroller-based teaching aid that will be developed is a teaching aid that will explain the basic concepts of mechanical energy practically and visually to prove the theoretical basis of the material. Researchers use Arduino as a teaching aid microcontroller because Arduino is a microcontroller whose programming language is quite easy to understand. (Saputri et al., 2017). Initialization of sensors into Arduino is also easy to implement because it does not use a complicated programming language. The use of physics learning teaching aids based on the Arduino Uno microcontroller is more directed to the use of tools with control systems that work automatically according to the command language of the program being run. The utilization of Arduino as a control system on teaching aids can also facilitate the reading of measurement results and minimize manual measurement reading errors caused by human error in the props used.

The development of Arduino Uno-based teaching aids has a major contribution in creating a digital technology-based learning aid performance. This development also has a good impact on increasing student achievement in cognitive, affective, and psychomotor aspects. (Hikmah et al., 2017) shows that the use of Arduino Uno-based teaching aids can improve students' psychomotor abilities in potential energy materials. The results of the study showed that the psychomotor abilities of students before using Arduino Uno-based teaching aids were 66%, but after using Arduino Uno-based teaching aids increased by 77%. The research has succeeded in improving students' psychomotor abilities in learning physics using Arduino Uno-based teaching aids, but in terms of the cognitive and affective domains, the research has not carried out measurements.

The innovation in this research is to create a tool that can help students to understand more complexly the concept of the potential energy of objects when they fall at maximum and minimum heights using Arduino Uno-based teaching aids so that the potential energy results obtained are following the theoretical basis, namely the potential energy produced. at the maximum point will be the maximum value and at the minimum point will be the minimum value. Judging from the explanation of the problems that have been explained, the researchers are interested in researching with the title Development of Potential Energy Teaching Aids Based on the Arduino Uno Microcontroller to Improve Student Achievement.

METHODE

The method used in this research is research and development. The research model used in this study is the ADDIE model which consists of 5 stages, namely: analysis, design, developt, Implementation, and Evaluation. The use of the ADDIE model in this study is suitable to be applied because the basis of the application of the model is oriented to the development of learning strategies and learning media. In addition, the application of the ADDIE model is used for constructional development, namely getting updates from the products developed (Arifin, 2012) In this study, the researcher limited the research to the Development stage due to limited manpower, time and cost so that the researcher was only limited to testing the feasibility level of the product or props made based on validation by media and material experts, knowing how much error the tool developed, and knowing increasing student achievement in cognitive, affective and psychomotor aspects.

The subject of development in this study is a validator consisting of media and material experts, each of whom is tasked with validating the products used in this study. the validator will assess whether or not the product development of teaching aids is made as an alternative to physics learning aids on the concept of potential energy. The media validator in this study consisted of 2 IKIP PGRI Pontianak lecturers from the Physics Education Study Program who were experts in assessing the feasibility of the media. The material validators consist of 2 IKIP PGRI Pontianak lecturers from the Physics Education Study Program who are experts in assessing the feasibility of the material. The product trial subject is aimed at grade 10 students of SMA Negeri 3 Sungai Kakap. The class used in the study was class 10 science at SMA Negeri 3 Sungai Kakap as a sample of the trial plan for the research product being developed.

The following are the stages of the flow used in this study as depicted in Figure 1. Figure 1 describes the stages of the flow in the research, namely using the ADDIE research model, but in practice, not all stages were carried out due to limited manpower, time and cost so that the researcher was only limited to testing the feasibility level. of the product.

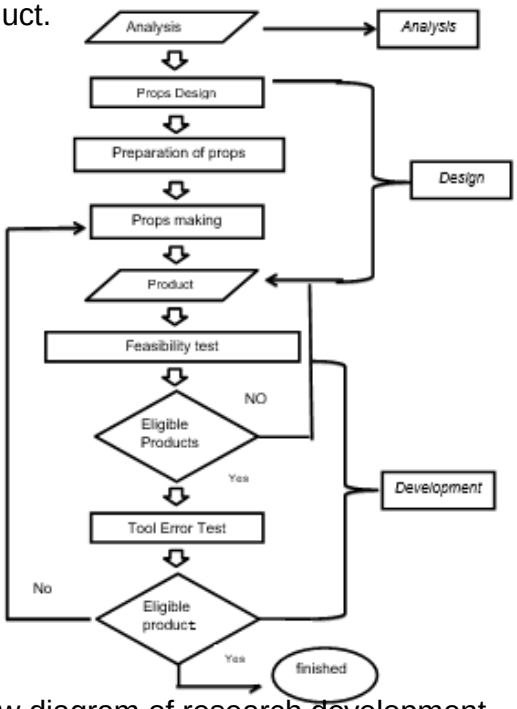


Figure 1. Flow diagram of research development

The research design will be divided into two, namely hardware design which consists of electronic circuit design, the second is software design. The electronic circuit design can be seen in Figure 2.

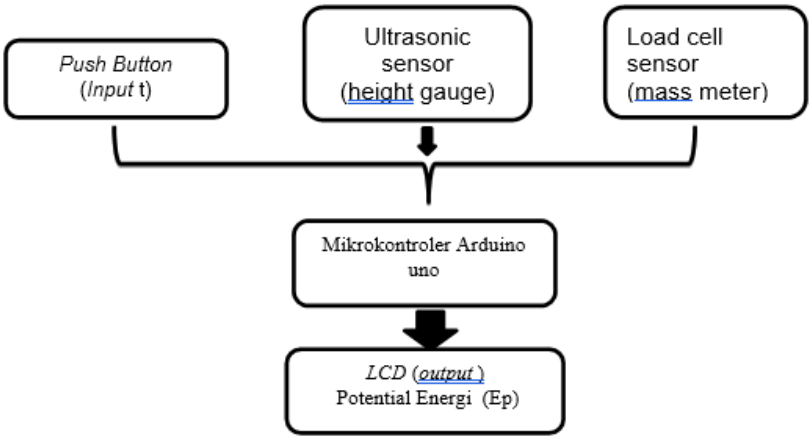


Figure 2. Block Diagram of Potential Energy Teaching Aid

Figure 2 illustrates the electronic circuit system that will be made. From the diagram, it can be seen that when the load cell sensor detects the weight of the object and the ultrasonic sensor detects the height of the object when it falls, the measurement results will be input into the Arduino Uno system to then be processed into output data to be displayed on the LCD.

Software design has a close relationship with the performance of the hardware made. The design software used is Arduino which controls the entire system. The flowchart of the experimental set of harmonic motions on a pendulum can be seen in Figure 3.

Figure 3 explains that the determination of the value of the mass and height of the object has been inputted so that potential energy will be obtained. Push-button is used to drop objects that fall at a certain height. The use of the push button has been initialized in the Arduino program so that when it is pressed simultaneously an object falls. If it is at ground level it will automatically turn off.

When the mass (m) and height (h) have been obtained with g as the acceleration of gravity of the earth (9.8). All variables that have been inputted into the Arduino system will be displayed on the LCD as the Arduino system screen. Calculate the potential energy of an object can be explained in Figure 4 below.

An object that is at a certain height for a certain reference plane has potential energy. This energy, according to its cause, is called gravitational potential energy. That is, this energy has the potential to do work by changing its altitude. The higher the position of an object from the reference plane, the greater the gravitational potential energy it has. Or it can be said that gravitational potential energy is the energy possessed by an object due to the influence of its place (position). This potential energy is also called rest energy because even objects at rest can have potential energy.

Potential energy is formulated.

$$Ep = m.g.h \quad (1)$$

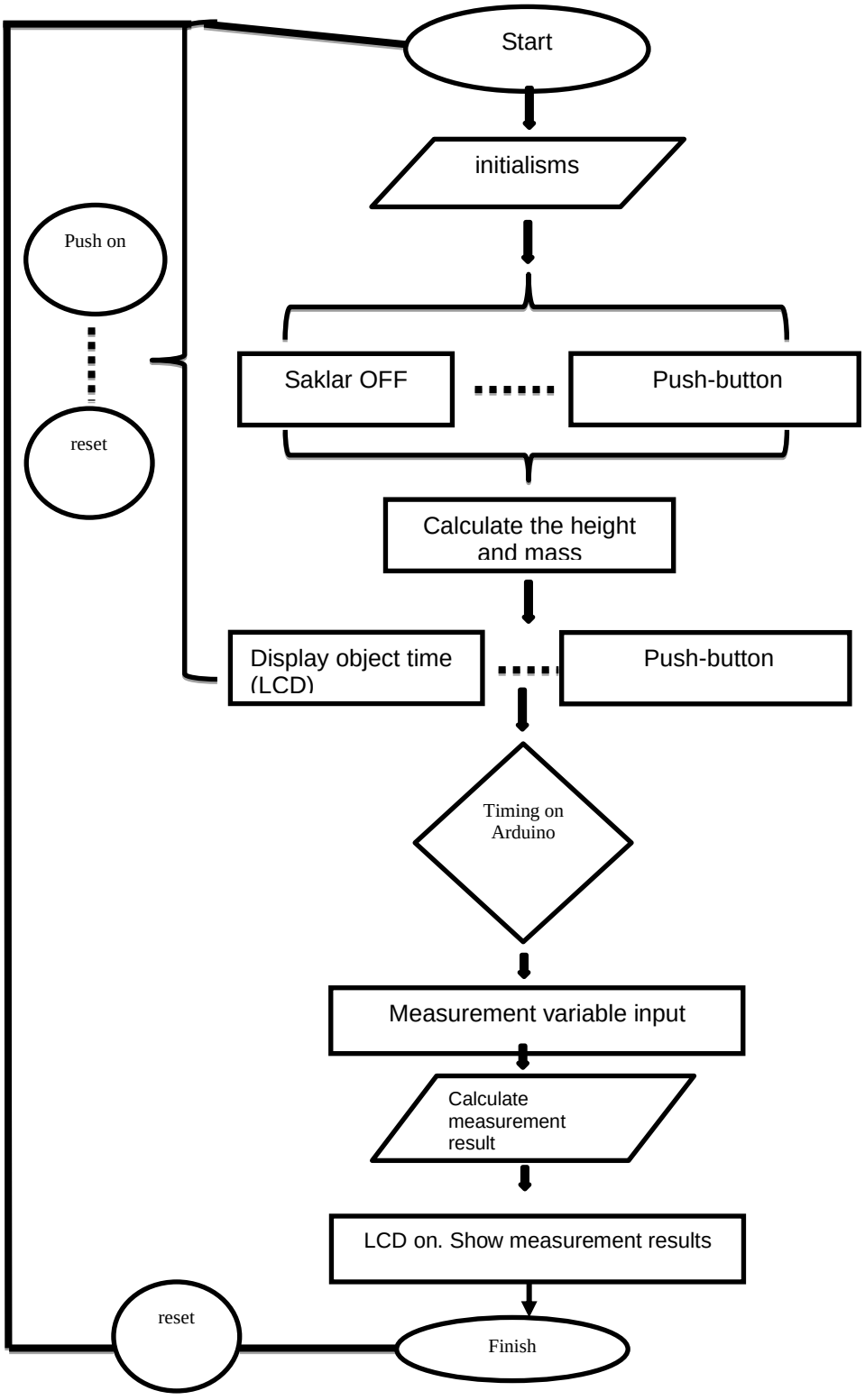


Figure 3. Flowchart/Flowchart Work Description Potential Energy Teaching Aid

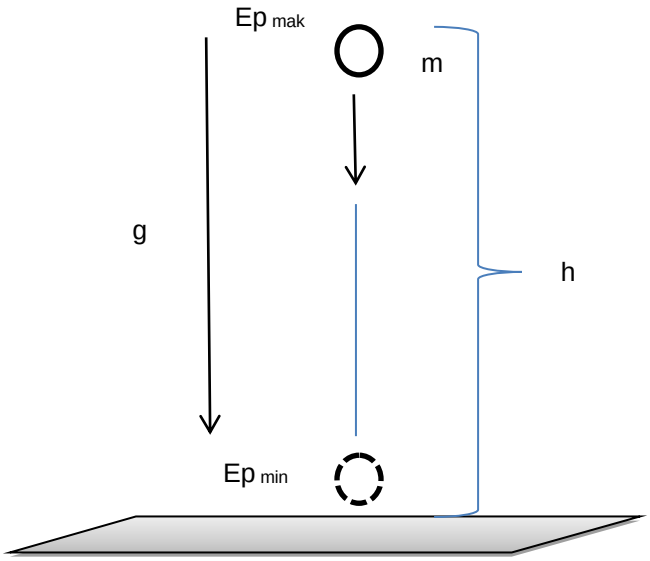


Figure 4. Potential Energy

To test the feasibility of the product, a feasibility assessment of the props is carried out. The feasibility test is carried out by media and material experts. The data analysis test used a Likert scale questionnaire to determine the criteria for the teaching aids after the assessment was carried out (Muchlis et al., 2018). The criteria used can be seen in Table 1 below.

Table 1. Qualitative Criteria for Assessment of Media Experts and Material Experts

Criteria	Value
Very Worthy	$80\% < P \leq 100\%$
Worthy	$60\% < P \leq 80\%$
Enough Worthy	$40\% < P \leq 60\%$
Less worthy	$20\% < P \leq 40\%$
Very Less Worthy	$0\% < P \leq 20\%$

After the product feasibility test has been carried out and is declared suitable for use, the next stage is to test the performance of the teaching aid by calculating the error value analysis carried out by comparing the difference between the limited error values and the actual specified values. The following is the formula for the percentage of errors that occur in the sensor according to (Idayu et al., 2019):

$$\% \text{ kesalahan} = \frac{nilai\ sebenarnya - nilai\ ukur}{nilai\ sebenarnya}\ x\ 100\% \quad \text{... (2)}$$

The data collected is then analyzed using descriptive statistical analysis by describing or describing the data that has been collected as it is without intending to make conclusions that apply to the general public or generalizations (Miarso, 2009). To determine the level of accuracy of the props made, the relative uncertainty equation is used. The following is the relative uncertainty equation used:

$$\text{KR} = \frac{\Delta x}{x} \text{ X } 100\% \quad \text{. . . (3)}$$

Information :
KR = Relative Uncertainty
∆X = Absolute Uncertainty
X = Measurement Result

Determine the level of confidence of the measuring instrument, the following equation is used:

$$\text{TK} = 100\% - \text{KR } (\%) \quad \text{... (4)}$$

Information :
TK = Confidence Level
KR = Relative Uncertainty

To determine the increase in student achievement in cognitive, affective, and psychomotor aspects, one can use the One Group Pretest Posttest Design research design, namely experiments carried out in only one group without a clear comparison group, which can be seen in Table 2 below.

Table 2. One Group Pretest Posttest Design

Group	Pretest	Treatment	Posttest
Experiment	T_1	X_1	T_2

Information:
X_1: The treatment is in the form of learning by using tools Arduino Uno Microcontroller-Based Potential Energy teaching aids
T_1 : Pretest is a test given to students before treatment in the experimental class

T_2 : Posttest is a test given to students after treatment in the experimental class

RESULTS AND DISCUSSION

1. Results

The research conducted is a type of research and development (Research & Development), the result of this research is to produce a product in the form of physics learning aids based on the Arduino Uno microcontroller assisted by sensors on potential energy materials. In developing the teaching aids the researcher uses the ADDIE development model, but the research development stage is limited to the development stage so that the research stages include the

analysis, design, and development stages. The activities carried out at each stage are as follows **:**

1.1. *Analysis*

This research begins with the analysis stage which at this stage there are several stages including problem analysis, material analysis, and research model analysis, and sensor analysis. In analyzing the problem, the researcher made observations, interviewed physics subject teachers, and interviewed students to find out potential problems in the physics learning process carried out. The results of interviews and observations made found obstacles that occurred in the learning process. These obstacles include the physics learning process that is carried out still using conventional learning methods, namely media-assisted lectures in the form of power points and textbooks that are still not able to attract interest and increase student learning motivation. The use of learning media in the form of teaching aids is not carried out due to the limitations of teaching aids in the laboratory. The involvement of students to be active in the learning process is also less due to minimal use of learning media that is interactive and fun for students such as the use of teaching aids.

Constraints such as students' difficulties in understanding the concepts of abstract physics are also one of the problems in the physics learning process. This factor is because the learning model is dominated by the delivery of theoretical explanations without demonstrating the physics concepts that occur. The learning that is carried out does not use teaching aids as a medium of learning to prove the concept of the material. The use of teaching aids is still limited to certain materials with minimal amounts plus the props used are conventional with old tools so that they have the potential to be damaged. The measurement of teaching aids is still using manual calculations and there has never been an innovation in control technology-based teaching aids to attract the props used, such as the use of the Arduino Uno microcontroller as one of the innovations in technology-based physics learning teaching aids (Straight & Materials, 2021).

The analysis is also carried out in determining the research model used in the development of teaching aids. The research model used must be following the topic of development studies to produce a valid and effective product to overcome the problems as described. The results of the analysis of the research model, in this research the model used, is the ADDIE research model. The use of this model is based on the topic of development studies, namely the development of physics learning media in the form of teaching aids. The research conducted (Nasrudin et al., 2021), the use of the ADDIE research model is suitable for use in this study because the basis for the application of the model is oriented to product development such as learning media in the form of teaching aids.

The analysis is also carried out in selecting the appropriate sensor for the development of potential energy props. After the analysis, it was determined several sensors were used in the development of this teaching aid, namely, ultrasonic sensors, and load cell sensors. Ultrasonic sensors are electronic modules that detect an object using sound. The ultrasonic sensor consists of a transmitter (transmitter) and a receiver (receiver). Transmitter serves to emit a sound wave towards the front. If there is an object in front of the transmitter, the signal will bounce back to the receiver. This sensor will calculate the echo time from the sonar reflection so that the distance from the sonar source to the object can be known (Straight & Materials, 2021).

Figure 5. Ultrasonic Sensor HC-SR04

A load cell is a sensor that can detect changes in mass caused by the force and gravity of objects. Changes caused by the force and gravity of the object will be used as an analog signal and will be forwarded to the transducer. The transducer functions to convert the analog signal generated by the load cell into an electrical quantity (AlRikabi et al., 2020).

The working principle of the load cell is calculated from the change in resistance that occurs due to the emergence of a strain on the metal foil strain gauges. The change in resistance is caused by applying a load on the elastic side so that the pressure changes according to that produced by the strain gauges. The results of changes in pressure on the load will be converted into stress by the existing supporting components. the load cell can be shown in Figure 6.

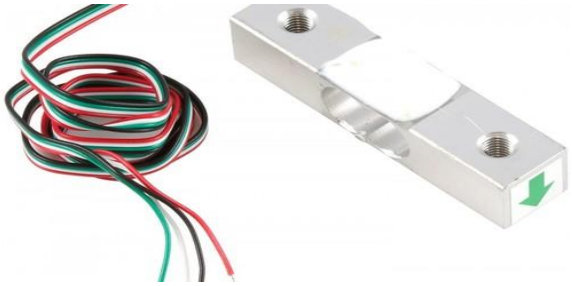


Figure 6. Sensor Load Cell

1.2. Design

In the design stage, several activities are carried out to produce a development product that is valid and effective for use. The activities carried out in this stage are as follows: Minimum System Design and Manufacture, Manufacture of Props Body or Chasing, Manufacture of teaching aids work system, Manufacture of Teaching Aid System Hardware, and Development of Props System Software.

The stages of designing and making the minimum system of teaching aids as a control circuit system are starting with the creation of a system circuit. Making the circuit aims to determine the location of the system to be made. Besides being used to determine the layout of components, the system circuit also has the advantage of reducing excessive budget costs. After making the scheme, the next step is to assemble the components according to a predetermined layout so that the components are well connected.

Making a Body or chasing props begins with designing the shape and size of the tool that is used as a reference for making tools. The making of the tool case

uses the basic material of 2 cm iron, the selection of this material is because iron has fairly good resistance to weather which is relatively high compared to materials such as wood so that the tools made can last a long time. After making the case, the next step is assembling and assembling the necessary components such as Arduino, load cell sensors, ultrasonic sensors, pushbuttons, jumper cables, and other components.

Making a working system of teaching aids has a control system that functions to process Arduino IC data which contains a program system to access data from ultrasonic sensor readings and load cell sensors which are used to calculate the height and mass of an object. The sensor will be given an order by Arduino to calculate the height and mass of the object automatically, the output or value of the sensor reading will be displayed on the LCD. In addition, Arduino will also receive an incoming signal from the push button which functions to input data for the quantity variables used in measuring object time. Strengthening the function of each component uses an Arduino input signal that gets a voltage of 5 V so that the work functions of the components run optimally so that the data reading by the Arduino system can run smoothly and the reading results are also accurate.

The design of the teaching aid software in this study was carried out by programming the Arduino system. This programming is carried out to regulate the main function of the teaching aid as a counter to the potential energy value of objects resulting from ultrasonic sensor measurements and load cell sensors along with other variables assisted by push buttons as buttons that function to input variable data needed in these measurements. The software created is used to activate the work function of the ultrasonic sensor as an object height measurement and load cell sensor as an object mass measurement and push button as an input button in the Arduino system. Arduino software will process the results of measuring the height of an object when it is dropped by calling the function of the ultrasonic sensor which is located exactly parallel to the end surface of the object so that when it is dropped the initial measurement by the sensor on the object does not have a large difference value when measured in an analog system. Arduino software also measures the mass of objects by calling the work function of the load cell sensor and calling the push button function to bring up the object time variable which is the final result of the system reading. The software system can be seen in Figure 7 below.

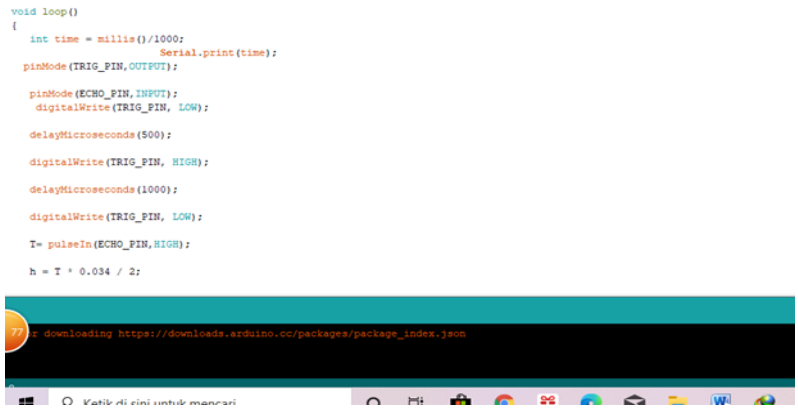


Figure 7. Potential energy display software system

1.3. *Development*

At this stage, the activities carried out are testing by material experts, media experts, and testing the accuracy of the developed teaching aids. In summary, the data from the development of physics learning media in the form of teaching aids based on the Arduino Uno microcontroller can be described as follows:

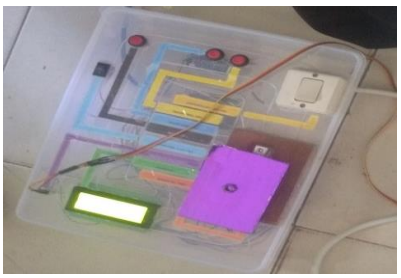
1.3.1. The results of the props feasibility test according to media experts

The media expert validator in assessing the feasibility of the Arduino Uno microcontroller-based physics learning teaching aids consists of 2 lecturers of the Physics Education Study Program of IKIP PGRI Pontianak who are experts in the field of media. The process of assessing product feasibility in the form of teaching aids by media experts is carried out by providing products in the form of teaching aids along with an assessment sheet in the form of a validation sheet with 25 assessment points covering aspects of durability, accuracy, speed of the tool system in reading measurement results, efficiency, and aesthetics. The process of assessing the teaching aids by media experts was carried out 2 times. After validation was carried out on the developed teaching aids, there were several suggestions and corrections by media experts in the validation process carried out so that they needed to be revised or improved as well as additions based on suggestions and input by media experts. The aspects assessed by media experts can be seen in Table 3.

Table 3. Obtaining Aspects of Media Validation Sheets

No.	Aspect	Percentage	Criteria
1	Tool Resistance	97,5%	Very Worthy
2	Aspects of Data Presentation	90%	Very Worthy
3	The speed of the tool software system in reading the measurement results	100%	Very Worthy
4	Tool Efficiency	93,3%	Very Worthy
5	Aesthetics	96,7%	Very Worthy
6	Aspects of Physical Appearance (Tool Shape)	92,5%	Very Worthy
	Total	570%	
	Percentage Average	95%	Very Worthy

The results of improvements or revisions by the media validator are based on the feasibility test assessment that has been carried out, namely For the steps for using the tool on the module add a description code/name on each switch to clarify the function of the two switches




Before revision After revision
Figure 8. Description of the Arduino Uno. switch

1.3.2. The results of the feasibility test of teaching aids according to material experts

The material expert validator in assessing the feasibility of the Arduino Uno microcontroller-based physics learning teaching aids consists of 2 lecturers of the Physics Education Study Program of IKIP PGRI Pontianak who are experts in the material field. The process of assessing product feasibility in the form of teaching aids by material experts is carried out by providing products in the form of teaching aids along with an assessment sheet in the form of a validation sheet with 12 assessment points on aspects of relevance to teaching materials, educational values, and implementation aspects.

The process of assessing the teaching aids by material experts was carried out 2 times. After validation on the developed teaching aids, there are several suggestions and corrections by material experts in the validation process that is carried out so that it needs to be revised or improved based on suggestions and input by media experts. The aspects assessed by media experts consist of 3 aspects which can be seen in Table 4.

From table 4, it can be concluded that based on the assessment by material experts, physics learning media in the form of teaching aids based on the Arduino Uno microcontroller on mechanical energy material received very suitable criteria for use in the learning process. The results of improvements and suggestions from material expert validators relate to the concept of potential energy. Whereat the maximum position the potential energy will be of maximum value, and at the minimum position, the potential energy will be zero.

Table 4. Obtaining Aspects of the Material Validation Sheet

No.	Aspects	Percentage	Criteria
1	Linkage with teaching materials	91,65%	Very Worthy
2	Educational value	100%	Very Worthy
3	Execution	100%	Very Worthy
	Total	291,65%	
	Average Percentage	97,21%	Very Worthy

1.3.3. Testing the accuracy of potential energy props

After testing by media and material experts, the next step is testing the accuracy of the props starting from ultrasonic sensor testing, sensor load cell testing, and testing potential energy values. Testing the ultrasonic sensor type HC-SR04 aims to determine the accuracy of the sensor and the error rate generated by the sensor. This test is carried out by comparing the distance value generated by the ultrasonic sensor HC-SR04 with the standard distance measuring instrument used, namely the ruler. The ultrasonic sensor HC-SR04 has an accuracy of 0.03 cm, while the ruler has an accuracy of 0.1 cm. The results of testing the ultrasonic sensor HC-SR04 are presented in Table 5.

Table 5. HC-SR04. Ultrasonic Sensor Reading Results

Measurement results Ruler (m)	HC-SR04. Ultrasonic Sensor Measurement Results					Average Error (cm) $s = \frac{5x - (y_1 + y_2 + \cdots + y_5)}{5}$	Percentage Error (%) $E = \frac{\Delta}{X} \cdot 100\%$
	1	2	3	4	5		
	Y1	Y2	Y3	Y4	Y5		
0,1	0,1	0,1	0,098	0,1	0,098	0,004	0,04
0,2	0,2	0,2	0,199	0,2	0,198	0,003	1,5
0,3	0,299	0,3	0,3	0,299	0,299	0,003	1
0,4	0,4	0,398	0,4	0,4	0,399	0,003	0,75
0,5	0,5	0,498	0,498	0,499	0,5	0,005	1
Evarage error							**0,658**

The data above shows that the ultrasonic sensor HCSR04 has a small error rate of 0.658%. It can be said that the ultrasonic sensor HC-SR04 is still in good condition and has a high level of accuracy. Based on the data obtained, a graph of the relationship between height measurements using a ruler and an ultrasonic sensor can be made which is presented in Figure 9.

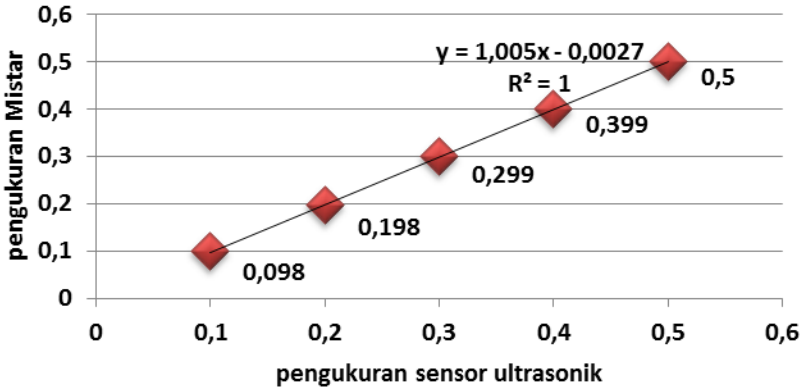


Figure 9. Graph of the relationship between digital ruler height measurement and ultrasonic sensor

Testing the load cell sensor with a capacity of 5 kg is carried out to determine the level of accuracy of sensor readings on the weight of the object and the percentage of error values that occur on the scales. In the load cell sensor testing system, it is done by calibrating the sensor readings with a digital scale which is commonly used as a reference in measuring the weight of objects in the Physics Education laboratory. The test results of the load cell sensor are presented in Table 6.

Table 6. Load Cell Sensor Reading Results

Real weight (gr) (X)	Load cell sensor measurement result (gr) (Y)	Error (gr) S = X – Y	Present age Error (%) $E = \frac{S}{X} . 100\%$
20	19	1	5
38	37	1	2,702
47	47	0	0
56	56	0	0
78	78	0	0
	Avarage error		1,540

The data above shows that the load cell sensor has a small error rate of 1.540%. It can be said that the load cell sensor is still in good condition and has a high level of accuracy. Based on the data obtained, a graph of the relationship between mass measurements using a digital balance and load cell sensor can be made as shown in Figure 10.

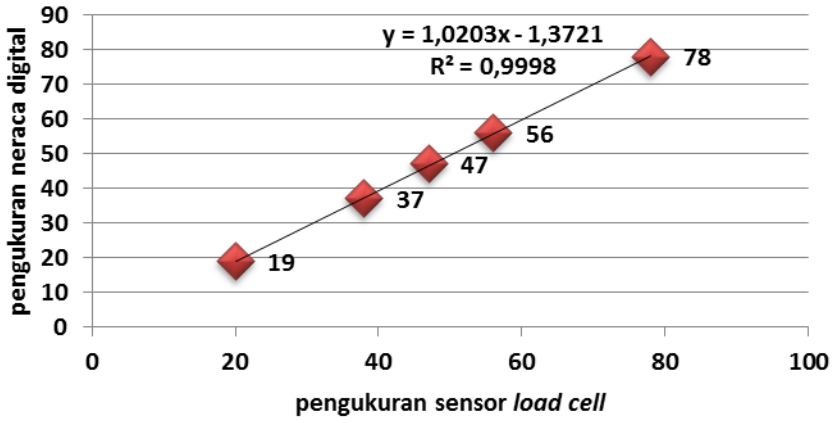


Figure 10. Graph of the relationship between digital balance mass measurements and load cell sensors

In the overall testing of the tool, the potential energy value (Ep) will be sought. The overall tool testing data is presented in Table 7.

Table 7. Data of Potential Energy Tool Test Results

m (kg)	h (m)	Highest point	Lowest point
		EP_1	EP_1
0,05	0,500	0,250	0
		0,250	0
		0,250	0
Σ		0,750	0
Average		0,250	0
Error result		$(0,250 \pm 0,00217)$	-
KR		0,86%	-
TK		99,14%	-
0,050	0,720	0,360	0
		0,360	0
		0,360	0
Σ		1,080	0
Average		0,360	0
Error result		$0,360 \pm 0,00199$	0
KR		0,55%	-
TK		99,45%	-

From the table above, it can be seen that at an altitude of 0.500 m with an object mass of 0.05 kg, the potential energy at the highest point is $(0,250 \pm 0,00217)$ Joule. For the level of confidence in the measurement, the results obtained are 99.14% with an accuracy level of 0.86%. At the lowest point, the potential energy generated is 0 Joules. For the level of confidence in the measurement, the results obtained are 99.27% with an accuracy level of 0.73%. At a height of 0.72 m with the same mass of 0.05 kg, the potential energy at the highest point is 0,360±0,00199 Joule. For the level of confidence in the measurement, the results obtained are 99.93% with an accuracy level of 0.07%. While at the lowest point the potential energy generated is 0 Joules. Based on the calculation of the data above, it can be seen that at the maximum height the object's potential energy has a maximum value, while at the minimum height the object's potential energy has a minimum value. Based on the data above, it can be concluded that the Arduino Uno-based physics learning aids developed can explain the concept of the potential energy of an object and can be used by students.

Figure 9. Props that have been developed

1.3.4. Student achievement results

After the stages of expert validation and testing the accuracy of the tool, the next stage is to find an increase in student achievement results in the cognitive, affective, and psychomotor domains. Cognitive learning achievement data obtained from the provision of learning achievement tests on potential energy material. Affective learning achievement data was obtained from the provision of effective questionnaires, and psychomotor learning achievement data was obtained from student observation sheets (pretest using a tool without an Arduino Uno sensor, and at the time of posttest using a developed tool). The distribution of student achievement scores on the cognitive, affective, and psychomotor aspects of the research results is presented in Table 8.

Table 8. Data Description of Students' Cognitive, Affective, and Psychomotor Learning Achievement Improvement

Aspect	% Average Pritest	% Average Postest	% Enhancement
Cognitive	60,5	75,3	14,8
Affective	70	78	8
Psychomotor	61,3	79,6	18,3

Table 8. shows that the description of the data on increasing learning achievement in the cognitive aspect with the average score for the pretest percentage is 60.5%, the post-test average is 75.3% with the percentage increase in value is 14.8%. To improve learning outcomes in the affective aspect, the average pretest score was 70%, the posttest average was 78% so that an increase of 8% was obtained. In the psychomotor aspect, the score increased by 18.3%, with an average pretest score of 61.3% and an average post-test score of 79.6%.

2. DISCUSSION

The media expert's average assessment of the props developed is included in the very decent criteria. The results of the data analysis described previously showed that the sensor-assisted Arduino Uno microcontroller-based physics learning teaching aids on mechanical energy materials had met the requirements and were feasible to be used as physics learning media. In line with research conducted by (Liana et al., 2020b) stated that the results of the feasibility carried out on the teaching aids obtained an average score of 95% overall assessment of the teaching aids with very feasible criteria by media experts so that the development of Arduino Uno-based sensor lamp props on energy materials was very good and received a positive response. Based on the research conducted (Mentsiev et al., 2019) it was found that the results of the media's eligibility for teaching aids obtained an overall average score of 77% with appropriate criteria by media experts. Research conducted (Atmoko et al., 2017) stated that the results of the media feasibility test carried out obtained an overall average percentage result of 82.85% with very feasible criteria by media experts. From the description above, it can be stated that the teaching aids developed have met the indicators set by media experts. Material expert indicators can be described as follows: 1) In the aspect of relevance to teaching materials, the percentage score obtained is 91.65% with very decent assessment criteria. These results indicate that the teaching aids made are compatible with the teaching materials used in the learning process. In addition, teaching aids also have conformity to the concept of the material used as a study in tool development. In terms of substance, the assessment of teaching aids on aspects of object clarity and physical phenomena presented received good criteria by the validator, this indicates that the developed teaching aids are suitable for use in the physics learning process. 2) In the aspect of educational value, the percentage score obtained is 100% with the assessment criteria very feasible. These results indicate that the teaching aids developed are suitable for use by the formal community because they have substance following the intellectual development of students. In addition, the use of tools can be used by teachers as a medium that can be used as a source of learning for students. 3) In the implementation aspect, the percentage score obtained is 100% with the assessment criteria very feasible. These results indicate that the developed teaching aids received a good rating by the validator when used. The use of tools is also effective in explaining the basic concepts of the material studied as the subject of research. The clarity in the description of the material presented received a good response from the validator because the teaching aids made were able to explain effectively and in detail the basic concepts of the subject being studied. In addition, the accuracy in the selection of media in the form of teaching aids also received a good response from the validator so that the tools made were valid and effectively used in the physics learning process.

Based on the results of the assessment analysis by material experts in Table 4, the average percentage score obtained is 97.21%. The average score of the material expert's assessment of the teaching aids developed is included in the very feasible criteria. The results of the data analysis described previously showed that the sensor-assisted Arduino Uno microcontroller-based physics learning teaching aids on mechanical energy materials had met the requirements and were feasible to be used as physics learning media. In line with research conducted by (Liana et al., 2020a) Based on the results of the feasibility carried out on the teaching aids, the average score for the overall assessment of teaching aids was

96% with very feasible criteria by material experts so that the development of mathematical pendulum teaching aids based on the Arduino microcontroller to train high school students' science process skills was very good and received a response. positive. Based on research conducted by (Idayu et al., 2019) Judging from the results of the feasibility of the material on the teaching aids, an overall average score of 78% was obtained with appropriate criteria by material experts. Research conducted by (Priharti et al., 2019). based on the results of the feasibility of the material on the teaching aids, the average score for the overall assessment of the teaching aids was 87% with very feasible criteria by material experts.

Judging from the results of the validation analysis of material experts on the Arduino Uno microcontroller-based physics learning teaching aids in Table 4, the results obtained by the assessment indicators are as follows: 1) In the aspect of learning motivation and understanding the concept of mechanical energy with teaching aids as media, the percentage score obtained is of 90.66% with very decent assessment criteria. In this aspect, the teaching aids that are made can motivate students in learning, this can be seen from the assessment responses of students who get very good criteria. The ease of understanding the material using these teaching aids also received a very good response from students, this shows that the developed teaching aids can help students learn physics. In addition, the use of teaching aids can make students active in the learning process because students' high curiosity to be able to use tools make the physics learning process more active and efficient so that the planned learning objectives can be achieved properly (Ma et al., 2012). The construction of the tool that is designed in such a way makes students interested in using it so that physics learning is more fun and not boring. Overall, the assessment points on this aspect received a good response from students. 2) In the aspect of operation and performance of teaching aids, the percentage score obtained is 87% with very decent assessment criteria. These results indicate that the props developed are easy to operate and use. The performance of the teaching aids when operated does not experience system errors so that the measurement results obtained are more optimal. In addition, the ready-made installation of tool components is not too complicated because it is equipped with the steps for using the props. On the other hand, the installation of the circuit on the components has also been arranged in such a way that students simply operate the tool system and use it in the learning process. 3) In terms of the quality of teaching aids, the percentage score obtained is 85.5% with very decent assessment criteria. In this aspect, the points that are assessed are tool resistance, system performance, and students' understanding of concepts. The durability of the tool got a good response from students, this shows that when used the tool has a durability of use that is not easily damaged, resistant to temperature and air so that its use can be used repeatedly. From the aspect of system performance, the developed tool received a good response from students, this shows that the tool works according to the established procedure. The speed of the sensor in reading the measurement results is one of the benchmarks that the tool developed has good acceleration quality in measuring the data carried out. In addition, in the aspect of understanding the concept of teaching aids that were developed also received a good response by students, this shows that the teaching aids developed can explain the basic concepts of material study to students, students are helped by the existence of teaching aids that can be used to improve understanding of concepts material more real (Rizky et al., 2021).

The next stage is testing the overall tool system by varying the height used in testing the tool. The results of testing the tool as a whole system, namely at an altitude of 0.500 m with an object mass of 0.05 kg, obtained potential energy at the highest point of 0.250±0.00217 Joule. At the lowest point, the potential energy generated is 0 Joules. At a height of 0.72 m with the same object mass of 0.05 kg, the potential energy at the highest point is 0.360±0.00199 Joules, while at the lowest point the potential energy is 0 Joules. Based on the calculation of the data above, it can be seen that at the maximum height the object's potential energy is of maximum value. At the minimum height, the potential energy of an object is of minimal value. Based on the data above, it can be concluded that the Arduino Uno-based physics learning aids developed can explain the basic concept of the potential energy of an object.

There is an increase in cognitive learning achievement results from statistical tests this is because there are several factors that affect the results of the study. The results of the observation of the first factor are differences in the learning process, learning carried out using teaching aids based on the Arduino Uno microcontroller, the majority of students play an active role in building knowledge obtained from the observed teaching aids to make learning on potential energy material clearer and concrete, the second factor, students who use real laboratories assimilation, accommodation, and equilibration processes run optimally, this is due to the length of practicum activities so that teachers can convey concepts from the material being taught. Students can maximally accept the concept of the material because students can see and do practical work directly accompanied by a more detailed explanation from the teacher. (Yektyastuti & Ikhsan, 2016).

There is an increase in the effective learning achievement of students who are given learning using teaching aids based on the Arduino Uno microcontroller. Physics learning uses teaching aids that are better developed in improving students' affective learning achievement. An increase in effective learning achievement due to interaction with teachers in learning using teaching aids is more effective. This is in line with research conducted (SARI & KIRINDI, 2019) from the results of the study it can be concluded that the teaching aids developed have a positive effect on student achievement and attitudes. When viewed from the affective learning achievement chart, which includes: willingness to accept lessons, pay attention to teacher explanations, desire to ask questions, willingness to study further subject matter, willingness to apply lesson results, careful in observation, honest in data collection, and cooperation well. The use of teaching aids will affect affective learning achievement which is dominated by internal factors of students, which are described by various activities and students' self-preparation to face the material to be delivered at home (Lestari & Supahar, 2020).

There is an increase in psychomotor learning achievement of students who are given learning using an Arduino Uno microcontroller-based teaching aid. An increase in psychomotor learning achievement is due to the props developed to train students' psychomotor skills. Teaching aids on potential energy material based on the Arduino Uno microcontroller can make students prepare experimental tools and materials, independence in carrying out experiments, skills in experiments, observation and data recording, performance in carrying out experiments, and the ability to compile experimental results. Potential energy teaching aids can improve students' psychomotor learning achievement (Idayu et al., 2019).

CONCLUSION

Judging from the results of product trials and discussions, in general, it can be concluded that the Arduino Uno microcontroller-based physics learning teaching aids are feasible to be used as learning media. Based on the research on the development of Arduino Uno microcontroller-based teaching aids, the following conclusions were obtained.

1. The feasibility of the Arduino Uno microcontroller-based physics learning teaching aids by the assessment of media experts obtained an average score of 95% with very decent criteria, and the feasibility of the Arduino Uno microcontroller-based physics learning aids by the material expert assessment obtained an average score of 95.83 % with very decent criteria.
2. Accuracy of physics learning teaching aids based on Arduino Uno microcontroller. For the level of confidence in the measurement, the results obtained are 99.14% with an accuracy level of 0.86%.
3. There is an increase in students' cognitive aspects of learning outcomes by 14.8%, affective aspects by 8%, and in the psychomotor aspect, there is an increase of 18.3%.

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