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Developing Physics Teaching Aids on Moment of Inertia Material using Arduino Nano and TCRT5000 Sensor

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Abstract

This study aims to establish the feasibility of developing a moment of inertia material teaching aid utilizing the Arduino Nano and the TCRT5000 sensor based on the opinions of media experts and material experts, the precision of the tool, and the responses of students to the created teaching aids. This study employed the ADDIE methodology comprising five stages: analysis, design, development, implementation, and evaluation. The average mistake percentage for acrylic material was 4%, cake mat was 13%, and rice paper was 10%, according to the findings of the accuracy of the teaching aid on the moment of inertia material based on Arduino Nano and the TCRT5000 sensor. Based on the data analysis, it can be concluded that the validation of teaching aids on the moment of inertia material based on the Arduino Nano using the TCRT5000 sensor by three media experts obtained an average score of 95% in the "very feasible" category and by three material expert validators on teaching aids obtained an average percentage of 97.33% in the "very decent" category and the guidebook an average percentage of 99% is in the "very decent" category. Student reactions to teaching aids received an 80 percent score in the "very suitable" area and a 79 percent score in the "good" category for the handbook. Thus, the Arduino Nano-based moment of inertia teaching aid utilizing the TCRT5000 sensor is ideal for school usage as a learning tool and can stimulate a desire to study.

Keywords: Arduino Nano; Moment of Inertia; Teaching aids; TCRT5000

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INTRODUCTION

Studying physics requires more than just the study of theory. In order to tackle a problem, especially one that is directly tied to everyday life, a student needs practical experience. According to Waris et al. (2015), "learning through the use of practicum tools provides students with the opportunity to observe and test the learned theories directly." This is a crucial reason why laboratory experiments should be utilized to illustrate abstract ideas (Hartati, 2010).

Based on the results of students' needs observation that has been carried out in several high schools in Bengkulu, seventy students strongly agree that there are learning media facilities and infrastructure in the form of teaching aids for the moment of inertia material. This material is typically not utilized in school practicums due to the lack of practicum tools that are not widely owned by several schools, especially in Bengkulu. Not only that, in several high schools in Bengkulu since the COVID-19 practicum, tools have not been used at all, especially at the moment of material inertia. Thus, students have not been able to comprehend the concepts that occur in the moment of material inertia. This motivates the researchers to develop teaching aids on the moment of inertia of materials using the Arduino Nano and the TCRT5000 sensor (Focus, 2022).

The Arduino Nano is used in making this educational tool because it has unique advantages compared to other microcontroller boards. The C language is the programming language used by Arduino. Besides that, the Arduino Nano board has a loader as a Micro USB port, making it easier for us to program the microcontroller.

Adequate teaching facilities must be offered to support the implementation of a fun learning process. In accordance with the principle that knowledge is obtained or stored by humans through the five senses, visual aids are learning aids (Apriliyanti et al., 2015). Visual aids are one of the learning tools used by students and teachers to demonstrate subject matter. The moment of inertia trainer is a tool that will be made in this study (Asyhari & Silvia, 2016).

The teaching aids developed must help students visualize the subject matter. Students can see directly how the process works on teaching aids; hence their use will increase student learning outcomes by facilitating a better understanding of the material's concept. Assessment of student learning outcomes can be assessed by looking at concept mastery and learning process skills. The importance of developing this teaching aid is due to the lack of learning media regarding the concept of the moment of inertia and the difficulty in obtaining teaching aids. Not only that, the reason for making this tool also adds to students' ability to understand the moment of inertia material which is difficult for students to understand.

In this study, the development carried out was to replace the Arduino board with Arduino Nano. According to research conducted by Sukindar (2017) and Dahlia et al. (2019), using Arduino Uno and the importance of developing teaching aids aims to make students understand what materials and styles affect the moment of material inertia. Thus, the number of pins or legs distinguishes between Arduino Nano and Arduino Uno. On the Arduino Nano, the number of pins or legs is 12. Meanwhile, there are 13 legs on the Arduino Uno. This research aims to evaluate the feasibility of actual teaching resources for moments of inertia.

METHOD

This study employed a Research and Development method. This study used the ADDIE model comprising five stages: analysis, design, development, implementation, and evaluation (Sugiyono, 2010). The ADDIE research model is applicable since it focuses primarily on developing learning strategies and learning media. In addition, the ADDIE model is utilized for construction development, especially to receive product updates that are being developed (Zaenal, 2016).

Student responses, media expert validators, and material expert validators are learning development materials (Razor, 2022). A media expert validator would assess the feasibility of the development tool product created as an alternative physics teaching material on the moment of inertia. The samples of the research product trial plans were presented to several schools in Bengkulu product trials (Muhlas & Marwani, 2020).

The flow stages used in this study, as depicted in Figure 1, are as follows.

Figure 1 illustrates the stages or flow of the research using the ADDIE research model.

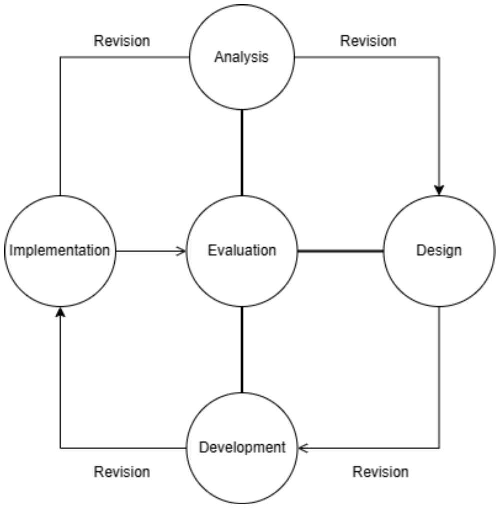

Figure 1 ADDIE research flow

The researchers only completed the analysis phase of the method described above. The researchers observed the needs of the students during the analysis phase. At the design stage, the researchers carried out several research designs in the form of a block diagram of the teaching aids system and a flowchart of the teaching aids. The next stage was the activities carried out in the form of designing, making tool bodies, making work systems, and developing software for teaching aid systems. The block diagram of the teaching aids system is shown in Figure 2.

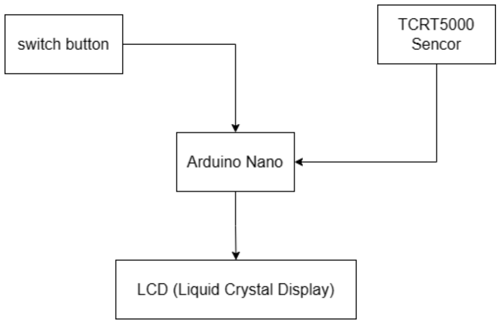

Figure 2 Teaching aids system block diagram

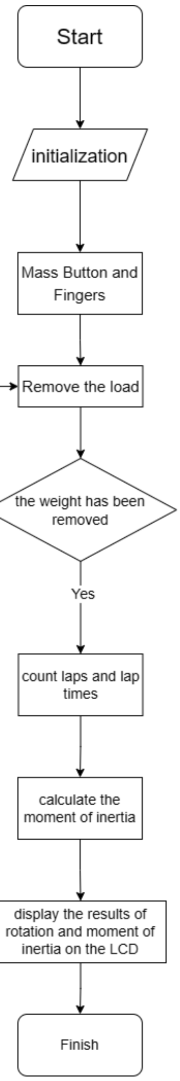

Figure 3 Teaching aids flow chart

Figure 2 illustrates the electronic circuit system that will be made. From these stages, it can be seen that when the TCT5000 sensor detects a line, the results will be input into the Arduino Nano system and then processed into data on the LCD.

Software design has a relationship with the performance of electronic devices or hardware. The Arduino Nano is the design software used, and it controls the Moment of Inertia experiment flow on the disc, as shown in Figure 3.

Figure 3 explains that the radius and mass values have been determined so that the number of turns and inertia would be obtained. The push button activates the mass and radius for calculating the number of turns and inertia.

The next stage was development. At this stage, the researchers conducted a media expert validation test, a material expert validation test, and a tool feasibility test. The test data analysis using a Likert scale questionnaire to determine the criteria for teaching aids after an assessment (Muchlis et al., 2018). The assessment criteria can be seen in Table 1.

Table 1 Qualitative criteria for assessment of media and material experts

Criteria	Value
Very Feasible	80% < $P \leq$ 100%
Feasible	60% < $P \leq$ 80%
Fairly Feasible	40% < $P \leq$ 60%
Less Feasible	20% < $P \leq$ 40%
Not Feasible	0% < $P \leq$ 20%

(Arikunto, 2021)

Using a formula, we analyzed the data to find the expert validator's reaction to the media and materials.

$$P = \frac{\sum x}{\sum x_i} x100\% \text{..........................(1)}$$

Explanation:

P : Percentage

∑x : Average answers every aspect

∑xi : The sum of the ideal values in the item

(Sugiyono, 2010)

The above-mentioned algorithm can be used to figure out how well students understand the visual aids that have been given to them. By calculating the error value analysis, which was done by comparing the difference in the limited error value with the actual value set, this study aims to evaluate the effectiveness of the teaching aids. According to Isa (2017), the formula for calculating the percentage of errors that occur at the moment of inertia of the teaching aid is as follows:

$$\%error = \frac{\text{actual value}}{\text{weight style}} x100\%$$

(2)

$$\%value\ error = \frac{\%\text{error}}{\text{number of trial}} x100\%$$

After the data was collected, descriptive analysis was used to analyze it by describing the data as it had been collected to avoid drawing any generalizations or conclusions.

The implementation phase was the next. The process of actualizing teaching aids was made real at the implementation stage. Everything created thus far would be installed and developed in accordance with its role or function for it to be carried out. This stage consists of two steps: practicing the moment of inertia of the teaching aids and seeing how the students react to the media that was made.

The evaluation was the final step. The evaluation stage was the stage where the success or failure of the product was determined. Formative and summative evaluation are two categories in which the evaluation stage was separated. Formative evaluation is an assessment that identifies the quality of the output, allowing for revisions or improvements to teaching materials. The summative evaluation assesses how well students have mastered the skills being taught. Typically, this assessment includes a pretest and a posttest (Nurdiana, 2019).

FINDINGS AND DISCUSSION

The research carried out a Research and Development (R&D) type, and the result of this research was to develop a product in the form of a material moment of inertia teaching aids using the Arduino Nano and the TCRT5000 sensor (Firdaus et al., 2022). In developing the teaching aids, the researchers used the ADDIE model, where the stages were Analysis, Design, Development, Implementation, and Evaluation. The activities carried out at each stage are as follows:

Analysis

From the results of observations, difficulties were found in the learning process. These challenges include the lack of practicum tools owned by schools, the continued use of traditional teaching techniques such as lectures with PowerPoint slides, and textbooks that still do not attract students' interest and increase their learning motivation. Due to the lack of interesting and interactive learning resources for students, such as visual aids, there is also a lack of student participation in the learning process.

One of the challenges in the learning process is when students have difficulty understanding the basic concepts of physics. This factor is because theoretical explanation learning models dominate the learning model without demonstrating the occurring physics concepts. Learning is done without using teaching aids as learning media to prove concepts and materials. The use of teaching aids is still very limited, with certain materials in minimal quantities, and the use of teaching aids is still conventional with old tools that have the potential to break.

Design

Planning and building a visual aid system as a control circuit system began with building a series of systems. The purpose of making a series is to determine the location of the system to be made. In addition to determining component layout, system suites have the added benefit of reducing budget overruns. After making the schematic, the next step was to assemble the parts and ensure they were all connected correctly.

Designing the shape and size of the teaching aids, which were used as guides when creating teaching aids, was the first step in creating the body of the teaching aids. This material was chosen to construct the moment of inertia box because it is lighter and more aesthetically pleasing than glass or plywood. After building the body, the necessary components, including the Arduino Nano, TCRT5000 Sensor, Switch Button, and Jumper Wires, must be added.

The control system was used to manage Arduino Nano IDE data, which contains a program system to access data from the TCRT5000 sensor readings to calculate the number of revolutions and moment of inertia. Arduino would automatically give the sensor orders to calculate the number of rotations and inertia, and the output or sensor reading value would appear on the LCD. Setting the function of each component uses an Arduino input signal, which receives a voltage of 5 volts so that the components' work function runs optimally and data reading by the Arduino system runs smoothly and accurately. The teaching aids look/ appearance is shown in Figure 4.

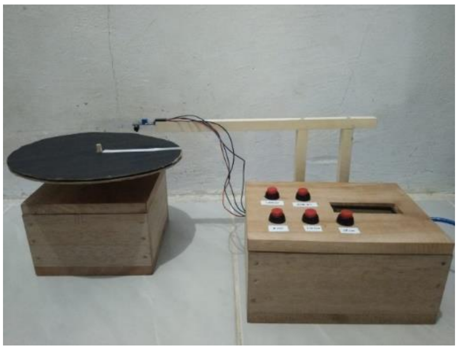

Figure 4 Teaching aids look/ appearance

In this study, the Arduino system programming tool software was designed to execute demonstrations. This programming identified the primary function of the educational tool as calculating mass and radius values, with the TCRT5000 sensor and push buttons used to pick the mass and radius values(Rosdianto, 2018). The software created was used to activate the working function of the TCRT5000 sensor as a revolution counter and a pushbutton as an input button on the Arduino system. When the load was removed, the Arduino software would process the results of the disk rotation by calling the TCRT5000 sensor function, which was located above the disk and parallel to the white line. The

Arduino software also measures inertia by calling the formula that has been entered into Arduino. The software system is depicted in Figure 5.

Figure 5 Software system display

Development

In 2019, Dahlia's teaching aids were designed by the researcher at the development stage. Sukindar (2017) developed an Arduino Uno-based moment of inertia teaching aid for students at the Private School of Madrasah Aliyah Ittikhadul Khoiriyah Muaro Jambi. The eleventh-grade SMA/MA students would be equipped with a moment of inertia learning tool based on the Arduino Uno. The researchers developed the Arduino. In this study, the researchers used Arduino Nano as a development tool. The Arduino Uno has 13 pins, while the Arduino Nano has 12 pins.

Testing by material experts, media experts, and the feasibility of the developed teaching aids was another activity carried out at this development stage. The information obtained from the manufacture of Arduino Nano microcontroller-based physics teaching aids can be summarized as follows: The feasibility test results of teaching aids according to media experts.

The process of determining the eligibility value of teaching aids by media experts in the form of assessment sheets and demonstrating products with a number of validation sheets, namely 16 assessment points that include tool efficiency, tool durability, aesthetics, technical components, and tool framework and components. The aspects assessed by media experts can be seen in Table 2.

Table 2 Aspects of the media expert validation sheet

Aspect	Percentage	Criteria
Tool Efficiency	97%	Very Feasible
Tool Resistance	89%	Very Feasible
Aesthetics	100%	Very Feasible
Tool Components	92%	Very Feasible
Framework and Tool Components	97%	Very Feasible

The products were provided in the form of validation assessment sheets to complete the assessment and visual aids with a total of 15 assessment points. Equipment feasibility, presentation feasibility, and language proficiency are three aspects of the handbook, along with their relation to teaching materials, educational value, and tool efficiency (Sunzuphy, 2021). Tables 3 and 4 show the elements assessed by material experts.

Table 3 Aspects of material expert validation sheet teaching aids

Aspect	Percentage	Criteria
Linkage with teaching materials	100%	Very Feasible
Educational Value	92%	Very Feasible
Tool Efficiency	100%	Very Feasible

Table 3 shows the results of validating the material on the teaching aids. The aspects assessed include linkages with teaching materials, including conformity with concepts and clarity of objects and phenomena. The value of education is in accordance with the development of students. In terms of tool efficiency, it is effectively used for the moment of inertia material.

Table 4 Aspects of the material expert validation sheet manual

Aspect	Percentage	Criteria
Content Eligibility	97%	Very Feasible
Eligibility of Presentation	100%	Very Feasible
Language Eligibility	100%	Very Feasible

Table 4 shows the results of the material expert validation in the guidebook. The aspects assessed include the content's feasibility, including the material's suitability and context. The feasibility of the presentation includes presentation techniques and data presentation support. In terms of language feasibility, they have conformity with the correct rules of the Indonesian language.

After testing the media and material experts, the next step was testing the accuracy of the result values of the teaching aids (Indriana, 2020). This test was carried out by comparing the results of the inertia value of the tool using the following formula:

$$I = \frac{\tau}{\alpha} \quad (3)$$

With torque (τ) is (F.R) and angular acceleration (α) is $\frac{\omega}{t}$.

$$I = \frac{F.R}{\frac{\omega}{t}} \quad (4)$$

Thus, the above formula becomes:

$$I = \frac{F.R.t}{\omega} \quad (5)$$

With omega (ω) = $\frac{2\pi}{T}$, while period (T) = $\frac{t}{n}$ then it becomes:

$$I = \frac{F.R.t}{\frac{2\pi}{T}} \quad (6)$$

Therefore, the inertia formula for the teaching aids is:

$$I = \frac{F.R.t^2}{2\pi.n} \quad (7)$$

Information:
I = Inertia moment
F = Gravity of the load
R = Radius
t = Time
n = Number of rounds

The results of testing props can be seen in Table 5.

Table 5 The results of testing teaching aids on acrylic discs

Mass (m)	Radius (R2)	Time (t)	Number of rounds (n)	Inertia (I)	T-count of inertia	Error percentage (%)
20gr	15 cm	25.00	15	0.014	0.019	7%
50gr	15 cm	16.12	15	0.018	0.020	4%
100gr	15 cm	10.87	15	0.019	0.018	2%
Total / Number of Trials						4%

The data in Table 5 shows that in the experiment using discs made from acrylic at different masses, the percentage error was 4%, which from the results of this percentage data can be said to be very feasible.

Table 6 The results of testing the teaching aids on the cake placemat disc

Mass (m)	Radius (R2)	Time (t)	Number of rounds (n)	Inertia (I)	T-count of inertia	Error percentage (%)
20gr	15 cm	9.62	15	0.032	0.029	16%
50gr	15 cm	8.17	15	0.058	0.053	12%
100gr	15 cm	7.76	15	0.011	0.009	11%
Total / Number of Trials						13%

The data in Table 6 shows that in the experiment using discs made from cake coasters at different masses, the error percentage was 13%, which from the results of this percentage data can be said to be very feasible.

Table 7 Results of testing teaching aids on rice paper discs

Mass (m)	Radius (R2)	Time (t)	Number of rounds (n)	Inertia (I)	T-count of inertia	Error percentage (%)
20gr	15 cm	12.66	15	0.052	0.051	26%
50gr	15 cm	11.65	15	0.012	0.010	2%
100gr	15 cm	9.07	15	0.014	0.013	1%
Total / Number of Trials						10%

The data in Table 7 shows that in the experiment using discs made from rice paper of different masses, the error percentage was 10%, which, based on the results of this percentage data, can be said to be very feasible.

Implementation

The moment of inertia of the teaching aids experiences suggestions or input in the early stages to make teaching aids ready to be tested on students. By looking at the students' responses to the questionnaire, this stage aims to determine the continuity of the moment of inertia of the teaching aids. Students can learn about using the moment of inertia trainer using the Arduino Nano and the TCRT5000 sensor they created, in addition to the viability of the moment of inertia trainer they made (Khasanah et al., 2020).

The students' responses to the microcontroller-based Arduino Nano physics teaching tool were recorded. The visual aids and student response sheets used in the assessment process amount to 15 assessment points. The teaching aids consist of two aspects, covering technical aspects and quality of content and objectives, and two aspects of the guidebook, covering quality of content and objectives as well as language. Tables 8 and 9 display elements of student responses.

Table 8 Aspects of student response to teaching aids

Aspect	Percentage	Criteria
Quality of content and purpose	81%	Very Feasible
Technical	78%	Feasible

Table 9 Aspects of student responses to the guidebook

Aspect	Percentage	Criteria
Quality of content and purpose	80%	Very Feasible
Language	78%	Feasible

Evaluation

This research phase only used formative evaluation, this is because it is adjusted to the purpose of this study, which is to find out the feasibility of the material moment of inertia teaching aids using Arduino Nano and the TCRT5000 sensor that has been made. The evaluation stage carried out in this study refers to the revision of the previous stages. The evaluation included revisions from media experts, material experts, and the results of student observations in the form of suggestions or input to improve the media so that it becomes more suitable for use as a learning medium.

Criteria that are very realistic include the average evaluation of training aids made by media experts, material experts, and student observations. The results of the data analysis discussed earlier show that the moment of inertia-based physics learning aid on the Arduino Nano microcontroller meets the criteria and is suitable for use as a physics learning medium. The feasibility results carried out by media experts obtained an average score of 86.75% with very feasible criteria. Based on research conducted by Sukindar (2017), it is known that the development of Arduino Uno physics teaching aids is very good and receives positive responses. The results of media validation in the research conducted bySukindar (2017) showed whether the teaching aids were appropriate; an average score of 90% was obtained, and the evaluation of all teaching aids with very appropriate criteria by media experts. The assessments performed are as follows: 1) The efficiency of the teaching aids in terms of determining whether the teaching aids are simple to use, simple to assemble, accurate in comparison to the previous tool, and relevant to the concepts being taught. 2) The tool's durability in the form of assessing the developed teaching aids' resistance to room temperature, the teaching aids' ease of maintenance, and the durability of the components on their original stand. 3) Aesthetics in the form of an attractive assessment of the developed teaching aids and components of the teaching aids that are neatly installed. 4) The technical component in the form of an assessment of the tool components is easy to find, and the teaching aids are easy to retrieve and store. 5) The framework and components of the tool are in the form of a robust tool framework; the TCRT5000 sensor functions well to measure inertia and count; the LCD has functioned well to display inertia and count data; and the Arduino Nano has functioned well as a microcontroller system teaching aid. In Table 2, regarding the material expert validation aspect sheet on tool efficiency, it is obtained by 97% with information on easy-to-use teaching aids, easy-to-assemble teaching aids, teaching aids that have more accuracy than the previous tool, and teaching aids related to the concepts being taught. Not only that, in the aspect of the media expert's validation sheet regarding the durability of the tool, an assessment of 89% was obtained with the assessment aspects, namely the tool's resistance to room temperature, ease of maintenance, and component durability in its original holder.

The percentage of the average score obtained in the development carried out by researchers based on the assessment analysis results by media experts in Table 2 is 95%. The criteria are very feasible considering the media expert's assessment of the average score of the resulting teaching aids. Based on the results of the data analysis, the moment of inertia of a material using the Arduino Nano microcontroller and the TCRT5000 sensor meets the criteria and is suitable for use as a physics learning tool. As for the aspects, namely the efficiency of the tool, including the ease of use of the tool and its assembly, it is more accurate than the previous tool, and in accordance with the concept being taught, a percentage of 97% is obtained. In terms of tool resistance, including resistance to room temperature, easy maintenance, and resistance of the components to their original mounts, a percentage of 89% was obtained. In the aesthetic aspect, because the tool is developed in an attractive way and the components are neatly installed, a percentage of 100% is obtained. In the technical component, including tools that are easy to obtain and tools that are easy to retrieve or store, the percentage is 92%. The framework and components of the tool include a strong tool framework, the sensor functions properly, the LCD functions properly, and the Arduino Nano functions properly; a percentage of 97% is obtained.

The results of the assessment aspects are as follows, based on the results of the expert validation analysis of Arduino Nano microcontroller-based physics teaching aids in Table 3 regarding teaching aids: 1) In the aspect of linkage with teaching materials, the percentage score obtained is 100% with very good criteria. In this regard, the teaching tools made are in accordance with the idea of moment of inertia and also clearly distinguish between objects and phenomena of moment of inertia. In this aspect, material experts assess according to the assessment criteria, namely that the moment of inertia teaching aids have compatibility with the concept and the moment of inertia teaching aids have clarity of objects and phenomena. 2) The percentage of scores achieved with very decent criteria in the elements of educational value is 92%. These findings indicate that the learning tools created can help students become more competent. In this aspect, the material expert validator conducts assessments with different criteria, namely teaching aids that are compatible with the level of student knowledge, increase competence in students, and have a level of compatibility with students' intellectual development. 3) The efficiency component of the tool yields a percentage of 100%. The findings show that the proposed teaching tool is easy to use and useful for introducing the concept of moment of inertia. With the very good category, the final average percentage score was 97.33%. In the results of the expert validation analysis of the Arduino Nano microcontroller-based physics learning aids in Table 4 regarding the guidebook, the following aspects of the assessment were obtained: 1) On the content feasibility aspect, a percentage of 97% was obtained with very decent criteria. From this aspect, the handbook is able to make it easier for students to understand the concept of the moment of inertia and is also able to explain the relationship between the moment of inertia material and everyday life. 2) On the presentation feasibility aspect, the percentage obtained is 100%. With the feasibility aspect of presenting the guidebook, it is hoped that students can understand the material with students' interest in the guidebook, which has interesting content in the form of Figures and is systematically arranged and can make students involved in understanding the moment of inertia material. On the aspect of language eligibility, the percentage obtained is 100%. From this aspect, the guidebook that is made must be in accordance with the language that is in accordance with the ~~EYD~~ and the use of terminology that is in accordance with the moment of inertia material, and the sentences in the guidebook must have a sentence structure that is easily understood by students. Thus, the resulting average percentage score is 99%, with a very feasible category.

In research conducted by Purnama et al. (2022),the students' response to teaching aids was 63% in the appropriate category. The researchers also did the same thing to find out the student's response. Based on examining the students' answers to the teaching aids made using the Arduino Nano microcontroller and the moment of inertia material in Table 5, a very good average score, namely 80%, was obtained. Based on testing students' answers to teaching materials made using moment of inertia materials that were built using the Arduino Nano microcontroller in Table 6 about manuals, an average score of 79% was obtained with the feasible criteria and provided suggestions in the form of tool boxes, which were made even more interesting by the color of the box and the efficiency of a simpler tool.

The next stage was testing the teaching aids by testing the tools at the Physics Education Laboratory, at Bengkulu University. The tests carried out by Dahlia et al. (2019), Sukindar (2017) and Purnama et al. (2022), it was solely tested with one material, namely acrylic. In this development, the tests were carried out with three disc materials, namely acrylic, cake mat, and rice paper. The results of testing the tool using acrylic obtained an average error percentage of 4%. By using a cake mat, an average error percentage score of 13% is obtained. An average error percentage score of 10% is obtained using rice paper. In the experiment using rice paper with a mass of 20 grams, a very large error was obtained compared to other experiments, namely 26%. This is because the mass is 20 grams, and the rotation is very slow with the desired number of revolutions, so the spin time is longer than the others and the resulting moment of inertia is also greater. Based on the results obtained above, it can be concluded that discs made from acrylic have a smaller error percentage than discs made from cake mats and rice paper. The effect that occurs is that the mass of each disc varies, namely the mass of the acrylic disc is 0.811 kg, the mass of the cake mat is 0.243 kg, and the mass of the rice paper is 0.303 kg. With a heavier mass, it will affect the speed when rotating. If acrylic is used, the turns are more stable than those on cake mats and paddy paper since the acrylic does not change shape. Meanwhile, the cake mat and rice paper slightly change shape and expand a bit. Thus, discs that are more accurate and have a lower percentage of error are acrylic.

The final stage, namely the evaluation stage, was carried out by media experts, material experts, and the results of student observations. In the evaluation carried out by media experts, it was found that the addition of a reset button on the teaching aids was needed or it could be replaced with an on/off socket to make it easier to reset the data you want to retrieve. In the evaluation carried out by material experts, it was found that the teaching aids were made even more interesting by giving color to the boxes and sensor support poles to make them look better. In the evaluation carried out by the students, the components of the tools in the box were tidied up even more, and the cables on the sensor support poles were given a holder for the sensor cables.

CONCLUSION

Using the TCRT5000 sensor, the researchers were able to create instructional aids for Arduino Nano-based moment inertia materials based on the development in this study. The researchers also validated the media expert to obtain the "very feasible" category, and validation of the material expert on the teaching aids aspect obtained the "very feasible" category, and the guidebook aspect obtained the "very feasible" category. The researchers also took data on students' responses to the tool in the aspect of teaching aids, which obtained the "very feasible" category, and the guidebook, which obtained the "feasible" category. Thus, the moment of inertia teaching aid can be applied to schools in order to increase students' understanding of the forces that affect the rotation and also increase student participation in more interesting material. Suggestions for the next development include attempting to place discs vertically in order to achieve better results.

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