Development of a Circular Motion Experimental Device Using an Arduino Uno Microcontroller

Azizahwati Azizahwati, M. Rahmad, Fahrun Hidayat
Physics Education – FKIP, Universitas Riau
Jl. HR. Soebrantas, Km. 12.5, Pekanbaru, 28293, Indonesia
azizahwati@lecturer.unri.ac.id

Abstract. The purpose of this research is to build a circular motion experimental device using the Arduino Uno microcontroller. This study uses the ADDIE model; Analyze, design, develop, implement and evaluate. This research was conducted until the develop stage. The research instrument was a validation sheet that was assessed by an expert. The data obtained were analyzed descriptively. The results obtained indicate that the experimental tool and manual for its use are declared valid by experts. This experimental tool can show a linear relationship between the angular velocity and the frequency of the dish with a relative error of 0.07%. The resulting experimental device is also capable of measuring frequencies and angular velocities for various discs.

1. Introduction
One of the subjects that have many difficulties in teaching physics concepts to students is circular motion [1,2]. Lack of regular circular motion learning media is a factor in the difficulties experienced by students [3]. Learning media can make learning optimal [4].

Students' understanding of abstract physics concepts becomes concrete with the help of teaching aids in learning. This results in students better understanding the concepts that teach. [5]. Several studies on circular motion have been carried out, including centrifugal props where the weakness is in unstable rotation [6]. Circular motion props use Arduino Uno but still need to be optimized, there is no guidebook [7].

The props to be developed must be better than the previous ones so that the angular velocity and frequency can be read on the screen (LCD) more accurately. The reading of the lap time uses a time sensor, namely photodiode and laser diode. This experimental device is controlled by the Arduino Uno microcontroller. Therefore, this study aims to build a circular motion experimental device using the Arduino Uno microcontroller.

The development of this circular motion experimental device is based on constructivism learning theory where students find their own concepts in learning [8]. Therefore, students in the implementation of learning need a circular motion experimental tool that is able to count the number of disc rotations so that the angular velocity and frequency are obtained accurately using the Arduino Uno microcontroller so that the concept can be proven. The ADDIE model was used in building this device. A valid experimental device is expected to be used in physics learning. The development of learning media is expected to be used as an alternative to improve the process and quality of education.
2. Methodology
This research uses the ADDIE (analysis, design, development, implementation, and evaluation) model research and development method. This research was conducted until the developing stage. The construction consists of: (1) props, namely mechanical and electronic devices, (2) manuals for the use of circular motion experimental devices. Before the experimental tool is validated by an expert, the tool must be tested for its functioning by looking at the level of measurement error. Evaluation criteria for the validation of teaching aids include: device functionality, comfort, aesthetics. Meanwhile, the evaluation criteria for the validation of a new book of experimental devices include: constructive, contextual, scientific approach, appearance, accuracy of content. The validation result data will be analyzed descriptively by calculating the average validity score of each assessment instrument for the experimental device. The validity scale is in the range 1 to 4. The assessment is said to be valid by the expert if it gets score of 3 or 4, while if it gets score of 1 or 2 it must be repaired.

3. Results and Discussion

3.1. Analysis
Needs analysis related to the concept of circular motion needs to be done. The literature study conducted shows that there are a number of problems with the circular motion concept. Previously developed experimental tools were still inaccurate because the tool rotation was unstable and the time was calculated using a stopwatch [9]. Previous research conducted using the Arduino Uno had an error rate of 4.75%, the disc size was not proportional using only one disc, the packaging tool was still less attractive and had not been validated by experts and manuals for using experimental tools had not been made [7].

3.2 Design
The design for the circular motion experimental device follows the flowchart in Figure 1. The concept of circular motion to be taught using an experimental device equipped with a manual for use will facilitate student understanding. The experiment guide book is designed in accordance with the provisions of the KEMRISTEKDIKTI [10].

Based on the flowchart, the experimental device design for the circular motion experimental device must use other intermediate components; photodiode, disc, flat mirror, ring, DC motor, laser, Arduino UNO microcontroller. The construction of the circular motion experimental device begins by making part of the tool frame shown in Figure 3.
Figure 2. Flowchart of the construction of a circular motion experimental device
3.3. Develop

3.3.1 Circular motion experimental device

Making the experimental device begins by assembling the components according to the design in Figure 3. Products that have been assembled will become integrated experimental tools, meaning that the tool is ready to use without having to be assembled first for use. The use of this circular motion experimental device can make it easy for students to understand the concept of circular motion.

Figure 4. (a) Experimental device for measuring angular velocity and frequency using an Arduino UNO microcontroller. (b) How to operate the circular motion experimental device

The experimental device has been made according to the design and has been through several revisions. The tool is designed to be able to calculate angular velocity and frequency with accurate accuracy. The dish that has been made using acrylic will rotate with the help of a 3V-9V DC motor [5]. This experimental device uses a laser as a light source. After the laser is turned on, the light will be forwarded towards the flat mirror then reflected by the flat mirror towards the photodiode sensor [11]. The light intensity coming from the laser will be received by the photodiode. This light intensity
greatly affects the photodiode resistance. Photodiode sensors can respond to visible and invisible light stimuli and convert the detected light intensity into currents.

**Table 1.** Data from measurement of angular velocity and frequency for n=1

| Disc | t (s)    | f (Hz) | $\omega$ (rad/s) | Error (%) |
|------|----------|--------|------------------|-----------|
| A    | 0.06     | 16.67  | 104.68           | 0.00      |
| B    | 0.07     | 14.30  | 89.90            | 0.14      |
| C    | 0.08     | 12.51  | 78.55            | 0.06      |
| Error rate |       |        |                  | 0.07      |

After the circular motion props are ready to be built, the error rate is assessed. The measurement results show that the average error of measuring angular velocity using three different types of dishes is 0.07%. There is a linear relationship between angular velocity and frequency. [12]. The laser beam which is directed at the disc at the start before and after turning back to one rotation is clearly detected by the photodiode so that the results can be accurate [11]. Furthermore, it is obtained a linear between the angular velocity and frequency [12]. This small error rate indicates that the props are functioning optimally.

**Table 2.** Recapitulation of the results of the experimental instrument validation

| No  | Indicator                         | Mean Score | Level of validity |
|-----|-----------------------------------|------------|-------------------|
| 1   | Devise function                   | 3.80       | Valid             |
| 2   | Learning Elements                 | 3.20       | Valid             |
| 3   | Convenience                       | 3.50       | Valid             |
| 4   | Aesthetics and Construction       | 3.60       | Valid             |
| 5   | Safety on the equipment           | 4.00       | Valid             |
|     | **Mean Score**                    | 3.60       | **Valid**         |

Furthermore, expert validation is carried out. The expert's assessment of the experimental device that was built was valid, namely a device that was suitable for use in classroom learning. The advice from experts regarding this experimental device is that in the future a permanent disc position is made.

3.3.2 **Handbook of circular motion experiments**

The operation of this circular motion experimental device is guided by a user manual so that students can easily use the tool. The manual for using the circular motion experimental device is made according to the rules suggested at the design stage.

**Table 3.** Recapitulation of the validation guide for the circular motion experimental device

| No  | Indicator       | Mean Score | Level of validity |
|-----|-----------------|------------|-------------------|
| 1   | Accuracy of content | 3.10       | Valid             |
| 2   | Appearance      | 3.50       | Valid             |
| 3   | Convenience     | 3.80       | Valid             |
|     | **Mean Score**  | 3.50       | **Valid**         |
The results of the expert judgment indicate that the manual is valid. In addition to how to use it, the manual is also equipped with various examples of contextual applications so that students can better understand the concept to be achieved [13,14]. This activity is expected to make the learning process effective [15].

4. Conclusion
The experimental device is able to show a linear relationship between angular velocity and frequency. Circular motion experimental devices are capable of measuring angular frequencies and velocities for various types of dishes. The analysis carried out shows that the circular motion experimental tool using the Arduino Uno microcontroller has a small error of 0.07%. The experimental device and the manual for the use of circular motion that were built were valid so that they were feasible to use. The validity of the experimental device that has been built shows that the tool is suitable for use in learning so that it can build students' conceptual understanding of the topic of circular motion.

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