Development of a set of props for collision based on Arduino Uno Microcontroller

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Abstract. This research aims to produce physics teaching props for senior high school in the collision topic. The props developed to consist of Arduino as the central controller, photodiode sensor, and infrared sensor as a ball motion detector attached to the tube's side as high as 100 cm. In its use, this teaching prop is also accompanied by student worksheets. The research design uses the Research and Development (R&D) method by using the 4D model, which includes: (1) define, (2) design, (3) develop, and (4) disseminate. Based on the media expert's validation results, the score was 80% for concept suitability, 81% for design suitability, and 83% for effectiveness and efficiency. Therefore, the product worthy of use as a learning media.

1. Introduction

Physics learning for almost all students is identical to memorizing formulas and calculation. Therefore, many students can only calculate using formulas without knowing the concept of physics [1]. The teacher feels that students prefer to count and avoid explaining the mathematical relationship with physics [2]. The same thing happens when studying collision materials, especially in finding the restitution coefficient. Mathematically, the restitution coefficient can be calculated using the negative ratio between the relative velocity immediately after the collision and the relative velocity before the collision [3]. The restitution coefficient concept can be more easily conveyed in classroom learning with learning media, such as teaching props [4].

Teaching props are tools to assist the learning process [3]. Props can help students to understand the concept better [5]. This is because the props used to demonstrate a topic to be easily understood by students [5]. Also, the props can improve the student learning outcomes [6]. The use of props in learning can make students actively involved, such as observing, conducting experiments, and demonstrations [7]. This learning activity supports the learning style of motion topics in physics, including collisions.

The development of props on the collision topic has been carried out previously, especially the restitution coefficient [3, 4]. The difference is that the research conducted by [4] used video tracking, while the study conducted by [3] used a microcontroller. When using a video tracking, the experiment must be recorded first [4], unlike a microcontroller.

The microcontroller uses as a digital system that applied in household and the electronics industry [8]. In general, the microcontroller is used as a control system, signal processing, instrumentation, and others [9]. In learning activities, the microcontroller can be used as a learning medium to improve...
practical skills and programming [10]. Microcontroller learning is currently one of the basic knowledges about technology and digital skills for students [11]. Therefore, Microcontroller expertise is critical in responding to technological challenges [12]. Thus, in this study, the development of teaching props and worksheets will be carried out to find a restitution coefficient. Where a tool developed using a microcontroller with the results of measuring the height of the object being practiced can be displayed directly.

2. Method
The research design uses the Research and Development (R&D) method by using the 4D model Thiagarajan, which includes: (1) define, (2) design, (3) develop, and (4) disseminate [13]. In this research, the stages are only up to the development stage. These are the explanation of each stage:

2.1. The define
The define stage is the stage for determining and defining the terms of learning. In this study, the define stage is divided into three parts, namely, curriculum analysis, analysis of students' needs and learning experiences and technology analysis.

2.2. The design
The design stage aims to design learning devices. The design activity begins with designing the outline (components) of the product to be developed, then continues by structuring the developed product systematics. The design of props shown in Figure 1.

1. Tube Acrylic: tube 100 cm long in diameter 8 cm for the free fall ball trajectory
2. Photosensor diode: the sensor functions as a light detector, interpreted the existence of an object that is blocked
3. Infrared sensor: red in charge of infrared-emitting light
4. Holder: as a holder or support sensor, tube, and stem so that it stays in position
5. Iron rod: support in each corner so that the tool is sturdy and not torn
6. Pedestal: the surface base functions the same as the holder located below as the boundary before the floor base
7. Empty gap: can be inserted additional media as a base reflected plane
8. Ball: observed object

2.3. The development
The development stage is the stage to produce a development product which is carried out in two steps, namely: (1) expert validation followed by revisions, (2) developmental testing. At the development stage a set of props consists of 1) Arduino Mega 2560, 2) Photo diodes 99 pieces, 3) Infrared 99 pieces, 4) Electronic black box, 5) USB cable, 6) Laptop Devices, 7) Acrylic tube 8cm diameter, 100cm high, and 3mm thickness, 8) Ball (tennis table), 9) Pedestal (acrylic, stainless steel, ceramic), 10) Track frames (iron bars, supports, handles / holders, bolts). Before the development testing, the researcher also calibrated the props.

3. Result and Discussion
The result of this development is a set of props. This set consists of student worksheets and teaching props. The student worksheet is used as a guide for the use of teaching props. Figure 2 (a) shows a set of teaching props and Figure 2 (b) shows the results of the student worksheets.
Figure 2. (a) a set of teaching props and (b) a cover of the student worksheets.

Product testing by media experts involved two physics lecturers at State University of Jakarta. This validation test aims to find out the feasibility of the product so it can be used as a tool or learning media that supports the process of teaching and learning activities. Table 1 shown the validation result in general. Based on the average score of validation results, the average score is 81.3% with the very good category. The aspects assessed in concept suitability include (1) showing the implementation of physics concepts in everyday life, (2) displaying the ball free falling to the floor and showing the restitution coefficient, (3) and the benefits of using tools do not cause verbalism. The aspects assessed in design suitability include (1) selection of props material, (2) durability of tools, (3) safety for students, (4) simplicity, (5) not out of date, (6) aesthetics, and (7) scale (height measuring). The aspects assessed in effectiveness and efficiency include (1) equipped with supporting media, (2) efficient use of tools, (3) readability and accuracy of measuring tools.

| No | Item                          | Score | Interpretation |
|----|-------------------------------|-------|----------------|
| 1. | Concept suitability           | 80%   | Good           |
| 2. | Design suitability            | 81%   | Very Good      |
| 3. | Effectiveness and efficiency  | 83%   | Very Good      |
|    | Average                       | 81.3% | Very good      |

Even though it is the same as using a microcontroller as a learning media in collisions topic, [3] results are different from this experiment. The product carried out by [3] uses two cars, which will crash [3]. While in this experiment using a dropped ball. Where the ball is dropped and the surface base on which the ball is touched can be changed. Figure 3 shown graph form of height versus time obtained by dropping a tennis table ball against an acrylic surface base starting at a height of 1 meter (100 cm). Based on Figure 3, the data that can be obtained are the maximum height of the ball. Then we can process data to produce the mean score, the restitution coefficient, the standard deviation, and the relative error shown in Table 2.
Figure 3. Graph form of height versus time obtained by dropping a tennis table ball.

Figure 3 shows the image pattern's similarity to the restitution coefficient's mathematical form [14]. This indicates that the props set used appropriately contextual and mathematically. The restitution coefficient results presented in Table 2 can be compared with other research, such as [15]. The Research from [15] determines the restitution coefficient of various sports balls, including table tennis balls. The surface base used is also varied, namely steel and wood. Based on the experiment [15], using hard ground (steel) will make the value of the restitution coefficient more significant than that of a soft base (wood). In table 2, where the experimental results show the average value of the restitution coefficient between a table tennis ball and a steel base is 0.800. The value obtained was not much different from the result [15], with the different 0.0076, namely 0.7924.

| Base Surface | Experiment to- | Restitution Coefficient | Mean  | Standard Deviation | Error (%) |
|--------------|----------------|-------------------------|-------|--------------------|-----------|
| Ceramic floor| 1              | 0.800                   | 0.806 | 0.015              | 1.822     |
|              | 2              | 0.800                   |       |                    |           |
|              | 3              | 0.815                   |       |                    |           |
|              | 4              | 0.815                   |       |                    |           |
|              | 5              | 0.801                   |       |                    |           |
| Acrylic     | 1              | 0.800                   | 0.805 | 0.023              | 2.818     |
|              | 2              | 0.795                   |       |                    |           |
|              | 3              | 0.815                   |       |                    |           |
|              | 4              | 0.816                   |       |                    |           |
|              | 5              | 0.801                   |       |                    |           |
| Steel       | 1              | 0.800                   | 0.800 | 0.011              | 1.330     |
|              | 2              | 0.806                   |       |                    |           |
|              | 3              | 0.806                   |       |                    |           |
|              | 4              | 0.800                   |       |                    |           |
|              | 5              | 0.790                   |       |                    |           |

The design visuals developed were made as attractive as possible, considering the research results conducted by [16] received input so that media visualization needs to be improved to make it more interesting. The development of this teaching prop is only up to the user test, which aims to obtain direct input in responses, reactions, student comments, and observers to the learning tools compiled.
So, in the next research it is better to do a field test related to using teaching props on learning motivation [17], the ability to solve problems [16], and other influences.

4. Conclusion
Based on the media expert's validation results, the score was 80% for concept suitability, 81% for design suitability, and 83% for effectiveness and efficiency. Therefore, the product worthy of use as a learning media. The suggestion for the next researcher is do a field trial and see the effect on the psychomotor, affective, and cognitive aspects of students.

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