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Development of a Practical Tool for Linear Momentum Collisions Using a Microcontroller

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ABSTRACT

Purpose of the study: This research aims to develop a linear momentum collision practical tool with a microcontroller so that the results obtained are more accurate, the time used is more efficient and the experiments carried out are more varied.

Methodology: This research is R & D research with development procedures, namely the potential and problem stages, data collection, product design, design validation, product design revision, product testing, final product. The subjects in this research were 2 media expert lecturers, 2 material expert lecturers, 20 pre-research students, 4 limited test students and 38 broad test students. Data collection techniques use observation, documentation and questionnaire techniques. The data analysis technique used is descriptive qualitative and quantitative .

Main Findings: The results of research on the development of linear momentum collision practical equipment with a microcontroller obtained a value from material expert tests of 3.8 with an ideal percentage of 94%, from media expert tests of 3.91 with an ideal percentage of 97.5%, from limited field tests of 3.93 with an ideal percentage of 78.75% and from tests The wide field is 3.85 with an ideal percentage of 77%.

Novelty/Originality of this study: The novelty of this research is the development of a linear momentum collision practical tool whose instrument part is for measuring the speed of objects determined using an ATmega 16 microcontroller and an ultrasonic sensor as a distance sensor. This learning media can be useful in improving the physics learning process to be more meaningful.

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1. INTRODUCTION

Physics is a branch of science that studies natural phenomena related to the environment and emphasizes understanding concepts [1]–[3]. Physics learning places greater emphasis on the process of student interaction with the environment while mastering physics concepts. Concept-based physics learning requires a high level of understanding that cannot be separated from assigning concepts, applying them in solving physics problems, and working scientifically [4]–[6]. Physics learning is often considered an abstract science presented in theoretical form [7]–[9].

Learning activities that can be used to improve students' abilities and process skills are carrying out practical activities [10]–[12]. Practicum is a learning activity aimed at giving students the opportunity to test and apply theory using laboratory facilities and outside the laboratory [13]–[15]. The importance of practical activities at school is because they can support students' thinking skills [16]. Practical activities are very important in science learning because science is based on observation and classification of facts in everyday life [17].

Learning is a process of communication interaction between learning resources, teachers and students. Communication interactions are carried out both directly in face-to-face activities and indirectly using media, where before using the media the learning model that will be determined is determined. Learning media is a tool used to facilitate the learning process. Various types of learning media include audio media, visual media, audio-visual media, and multimedia. The media used in learning must be adapted to the teaching material to be delivered in order to obtain maximum results.

The Basic Physics Practicum II course, Linear Momentum Collision module, is practiced to facilitate students' understanding of the concept of momentum. The limitations of the equipment both in terms of number and condition of the typing timer as a tool for measuring the speed of objects resulted in the practicum not being able to run as it should. Apart from that, using a typing timer also takes a long time when assembling experimental equipment and when carrying out calculations. The Basic Physics Practicum I course is one of the main courses (MKU) of the study program that must be taken by students of the Physics Education Department, Faculty of Science and Technology, UIN Walisongo Semarang. This course weighs 1 credit and is taken in semester 1. The practicum "Linear Momentum Collisions" in the Basic Physics Practicum I course aims to test the applicability of the law of preserving linear momentum in collisions [18], [19]. The law of conservation of momentum states, in a perfectly elastic collision between two objects in a system, the total momentum before the collision is equal to the total momentum after the collision [20], [21]. The linear momentum collision practicum will test the applicability of the law of preserving linear momentum between two dynamic trains on a rail [22].

The linear momentum of a particle is a vector quantity $\vec{p}$ which can be calculated by operating other quantities in the form of object mass (m) and the speed of the object ($\vec{v}$) [23], [24]. In the Linear Momentum Collision practicum, practitioners can use a balance to determine the mass of colliding objects [25], [26]. Meanwhile, to determine the speed, practice using a ticker timer. The use of a timer to measure speed has several shortcomings that result in discrepancies in the results. Among them is that friction between the typing tape and the typing timer can hinder the speed of objects. The typing timer can only measure speed when the object moves away from the typing timer (one direction). Meanwhile, in a collision, it is very possible for objects to move back and forth (in both directions), making it possible to develop a practical tool for linear momentum collisions. Practical tools are needed that are able to determine the speed of objects accurately and are easy to use to overcome this problem. Researchers developed a practical tool for linear momentum collisions, especially on speed measuring instruments, using a microcontroller.

In line with previous research, learning media plays an important role as a tool for creating an effective learning process in understanding physics concepts [27]. Previous research developed props for the conservation of momentum project using sensors. As a generalization of previous research, this research was carried out to develop learning media in the form of a linear momentum collision practical tool based on an ATmega 16 microcontroller with an ultrasonic sensor to determine the speed of objects.The novelty of this research is the development of a linear momentum collision practical tool whose instrument part is for measuring the speed of objects determined using an ATmega 16 microcontroller and an ultrasonic sensor as a distance sensor. This learning media can be useful in improving the physics learning process to be more meaningful.

Practical tools with microcontrollers can motivate students to study electronics and instrumentation in more detail and provide more effective and efficient results. The product designed is a tool for determining the speed of objects that will be used in linear momentum collision practicals. The product specifications are a distance measuring device that works digitally using an AVR ATmega 16 microcontroller with an ultrasonic sensor. Ultrasonic sensors detect the distance of objects and send data to the microcontroller. The microcontroller stores data in the form of distance from the ultrasonic sensor every 0.2 seconds. Microcontrollers are smart chips that are becoming a trend in control and automation. With many types, memory capacities, and various features, microcontrollers are the choice in mini processor applications for small-scale control. The AVR (Alf and Vegard's Risc Processor) microcontroller from Atmel uses a RISC (Reduced Instruction Set Computer) architecture, which means the processor has a fewer program instruction set compared to the MCS-51 which implements a CISC (Complex Instruction Set Computer) architecture.

The ATmega type AVR has several series, including the ATmega 16. The ATmega16 has a standard 40 pins which have their own functions. Ultrasonic is the term for a type of sound above the sound limit that humans can hear. An ultrasonic sensor is a sensor that utilizes ultrasonic wave emissions. The ultrasonic sensor consists of an ultrasonic transmitter circuit called the transmitter and an ultrasonic receiver circuit called the receiver. The generated ultrasonic signal will be emitted from the ultrasonic transmitter. Based on the background above, the researcher aims to create a linear momentum collision practical tool based on the

ATmega 16 microcontroller with an ultrasonic sensor to determine the speed of objects. So this research is important to carry out so that the results obtained from the practicum are more accurate, the time used is more efficient and the experiments carried out are more varied.

2. RESEARCH METHOD

This research is an R & D (Research and Development) research with development procedures, namely (1) potential and problem stages, (2) data collection, (3) product design, (4) design validation, (5) product design revision, (6) product testing, (7) final product. The subjects in this research were 2 media expert lecturers, 2 material expert lecturers, 20 pre-research students, 4 limited test students and 38 broad test students. Data collection techniques use observation, documentation and questionnaire techniques. The data analysis technique used is descriptive qualitative and quantitative. The model in this development research is a procedural model, namely a model that is descriptive and outlines the development steps [28]–[30].

The data collection techniques in this research use observation, documentation and questionnaire techniques. Data analysis techniques use two types of data, namely qualitative data and quantitative data.

- The qualitative data in this research is in the form of quality value categories for practicum modules based on module quality assessments by 2 lecturers who teach Basic Electronics Practicum I, lecturers who are experts in teaching materials, and lecturers who are media experts and respondents. Qualitative data in the form of input from 2 media experts, namely Musa Mohammed Girei and Farokh Feizi. Then 2 lecturers who taught the practicum were adjusted to carry out product revisions. Meanwhile, qualitative data that has been quantified by giving scores and rankings to each indicator is analyzed quantitatively so that the quality of the module is known after it has been tested.5
- Quantitative data is in the form of an assessment score for each indicator with 4 assessment criteria carried out by experts on the practical equipment quality assessment sheet. The quality assessment sheet for the linear momentum collision practical equipment in the Basic Physics Practicum II course uses a Likert scale with the provisions,
  4 = very good/ very capable/ very suitable
  3 = good/ able/ appropriate
  2 = less/not suitable
  1 = very poor/unable/very inappropriate

3. RESULTS AND DISCUSSION

3.1. Product Prototype Description

This research began by conducting a preliminary study by distributing questionnaires to lecturers in charge of the Basic Physics Practicum I course. The questionnaire was used to obtain data regarding the implementation of the Basic Physics Practicum I module, Linear Momentum Collision. The questionnaire consists of 4 question items using a Likert scale with the following 5 criteria:

5 = very good/ very capable/ very suitable
4 = good/ able/ appropriate
3 = Sufficient/Fairly Appropriate
2 = less/not suitable
1 = very poor/unable/very inappropriate

The results of the questionnaire obtained an average data of 2.6 and an ideal percentage of 53% which was included in the poor category. The product developed is a linear momentum impact practical tool with an ATmega 16 microcontroller and an ultrasonic sensor which has the following specifications:

1. An object distance measuring tool that works digitally using an AVR ATmega 16 microcontroller with an ultrasonic sensor programmed using C language.
2. The ultrasonic sensor detects the distance of objects and sends data to the microcontroller.
3. The microcontroller stores data in the form of distance from the ultrasonic sensor every 0.2 seconds.

The part of the tool developed is an object speed meter that uses an ultrasonic sensor. The ultrasonic sensor measures the distance of objects every 0.2 seconds. Speed can be obtained by dividing the distance the train moves per 0.2 seconds.

Product creation consists of 2 stages, namely hardware design and software design. In designing this tool, the hardware used is a push switch (switch button), LCD display, ultrasonic sensor, ATmega16 microcontroller minimum system and ATmega 16 IC. In hardware design, digital ports from the ATmega 16 minimum system are used to connect to the LCD, ultrasonic sensor and push switch (button). The use of these ports can be seen in the table below.

Table 1. Use of ATmega 16 Sismin PORT

PORT Sismin ATmega 16	Komponen
D0	Tombol START
D1	Tombol UP
D2	Tombol DOWN
D3	Tombol SHOW
B0	Echo PIN Ultrasonik
C0	LCD 16x2
C1	LCD 16x2
C2	LCD 16x2
C4	LCD 16x2
C5	LCD 16x2
C6	LCD 16x2
C7	LCD 16x2

After the hardware is arranged properly, the next stage is software design, namely compiling a program that will be inserted into the ATmega 16 IC so that the overall microcontroller can operate. The system software is written using C language, and the compiler used is CV AVR.The flowchart can shOow that when the system is turned on, the system initializes the tool. Next, the system displays the characters "press START" on the LCD to start taking data. After the START button is pressed, the system will collect data in the form of the distance of the object in front of the ultrasonic sensor every 0.2 seconds. The system retrieves data for 4 seconds, so the system retrieves data 20 times. Next, the system displays the characters "press SHOW" on the LCD to display the data that has been taken. Next, press the UP and DOWN buttons to view the data for the next time interval.

The product prototype in the form of a linear momentum collision practical tool with a microcontroller can be seen in the picture below:

Figure 1. A series of practical equipment for linear momentum collisions

3.2. Product Test

Product testing is carried out to obtain the quality of the practical tools being developed. Product testing consists of stages, namely expert testing and limited field testing. Material expert assessment is carried out to determine the quality of the practical tools that have been developed. The material expert assesses the linear momentum collision practicum tool and then provides suggestions and input according to the material expert's assessment grid. These suggestions and input are used to revise the practicum tools until good quality practicum tools are obtained in terms of material. The material expert test was carried out by 2 expert lecturers to get a comparison of the quality of the practical tools and the average value was taken from both of them. The two lecturers are Qisthi Fariyani, M.Pd. (lecturer in Basic Physics Practicum I class PF-1B) and Biaunik Niski Kamila, M.Sc. (lecturer in Basic Physics Practicum I class PF-1A).

The following are the results of the assessment by material expert lecturers regarding the linear momentum collision practical tool with a microcontroller as in the table below:

Table 2. Results of assessment by material experts

Materials Expert	No. Indicator	Velue	$\sum$	$\bar{x}$	%
Qisithi Fariyani	1	4	19	3.8	95%
	2	4			
	3	4			
	4	4			
	5	3			
Biaunik Niski Kamila	1	3	19	3.8	95%
	2	4			
	3	4			
	4	4			
	5	4			

Based on the table above, overall the average value of 3.8 is obtained with a feasibility percentage of 95%, so that based on the ideal calculation results, the practical tools that have been developed according to material experts are categorized as very good. As for the results

The media expert's assessment was carried out to determine the quality of the product as a practical tool for linear momentum collisions in the Basic Physics Practicum I course. The media expert assessed the practical tool and then provided suggestions and input according to the media expert's material assessment grid. The assessment carried out by 2 media experts will later be used to revise the practicum tools that have been developed until good quality practicum tools are obtained. The two media experts are Musa Mohammed Girei and Farokh Feizi. The following are the results of the assessment by media experts regarding the linear momentum collision practical tool with a microcontroller as in table 3.

Table 3. Assessment results by material experts

Materials Expert	Indicator Number	Value	$\sum$	$\bar{x}$	%
Musa Mohammed Girei	1	4	19	3.8	95%
	2	4			
	3	4			
	4	4			
	5	3			
Farokh Feizi	1	3	19	3.8	95%
	2	4			
	3	4			
	4	4			
	5	4			

Based on the results of media experts, the overall average value of 3.91 was obtained with a feasibility percentage of 97.9%, so that based on the results of ideal calculations, the practical tools that have been developed according to media experts are categorized as very good.

After field testing, the linear momentum impact practicum tool was tested on a large scale. Wide-scale field tests were carried out on 5 practicum groups for the 2016 Physics Education class A and 7 practicum groups for the 2016 Physics Education class B. From the wide-scale field tests, the overall student response data was obtained with a score of 3.85 and an eligibility percentage of 77% with a good category.

3.3. Data analysis

The data used in this research are qualitative data and quantitative data. Qualitative data is obtained from observation and documentation. Meanwhile, quantitative data is obtained from scoring each indicator point with 4 and 5 assessment criteria. This research uses procedural development procedures based on the theory put forward by sugiyono which is simplified into (1) potential and problem stages, (2) data collection, (3) product design, (4) design validation, (5) revision product design, (6) product testing, (7) final product [31].

This research began with the experience of researchers in the Basic Physics Practicum who experienced difficulties in the linear momentum collision module practicum, so the researcher distributed a questionnaire for implementing the linear momentum collision practicum to obtain further information. Information was obtained that students had difficulty determining the momentum before and after the collision. This is because the practical tool for determining speed (typing timer) causes friction and can only determine the speed of objects moving away from the typing timer. Meanwhile, in a collision event, it is very possible for the object to move in the opposite direction from before and after the collision.

Based on the analysis of the questionnaire for the implementation of the Basic Physics Practicum I linear momentum collision module, the researchers took the initiative to develop this tool. The development was carried out to make it easier for students to carry out practical work on linear momentum collisions, especially in determining the speed of objects both before and after the collision. In addition, after development it is very possible for the practitioner to be able to vary the collisions even more.

The prototype development stage begins with selecting the type of microcontroller that will be used. In this research, researchers used an ATmega 16 microcontroller considering the affordable price and quite a lot of references. Then select the sensor to determine the speed. The linear momentum collision practicum tool with a microcontroller was tested on a limited basis on 1 group in the Basic Physics Practicum I course for class PF-IA. The results of the limited test of the linear momentum collision practical tool with a microcontroller obtained a value of 3.93 with an ideal percentage of 78.75% so it can be categorized as good (B). The next stage was that the linear momentum collision practicum tool with a microcontroller was tested extensively in the Basic Physics Practicum I course for classes PF-IA and PF-IB. The results of extensive testing of linear momentum collision practical equipment with a microcontroller obtained a value of 3.85 with an ideal percentage of 77% which is included in the good category (B).

The next stage is that the linear momentum collision practicum tool can be used as one of the modules in the Basic Physics Practicum I course. The linear momentum collision practicum tool with a microcontroller was disseminated in the Basic Physics Laboratory, Faculty of Science and Technology, UIN Walisongo Semarang.

3.4. Development Results Prototype

The product resulting from this research and development is a linear momentum collision practical tool with a microcontroller. This practical tool aims to calculate the amount of momentum before and after the collision. The product in the form of a tool for determining the speed of objects can be seen in Figure 2 dan figure 3. The series of linear momentum collision practical tools resulting from the overall development can be seen in the figure below.

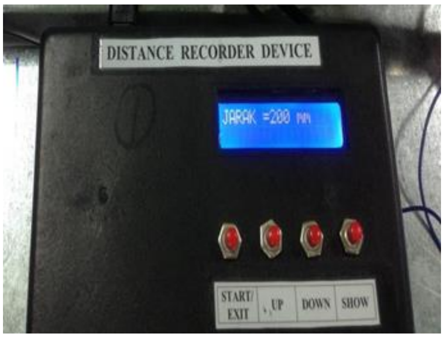

Figure 2. Layout of an object speed measuring device

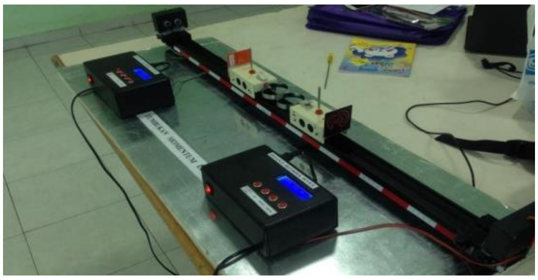

Figure 3. Prototype resulting from the development of a linear momentum collision practical tool with a microcontroller.

The image above shows the layout of the object speed measuring device and the prototype resulting from the development of a linear momentum collision practical tool with a microcontroller. Based on the results of previous research, it is very important to develop practical teaching aids in science learning, teaching aids can be used as media in science learning to carry out effective teaching, improve student learning outcomes [32]. This research has an impact on the fields of education and research, namely that it can revolutionize the way students learn physics, especially in understanding and visualizing the matter of conservation of momentum in collisions. Then researchers can also use the developed tools to conduct experiments or validate theoretical models.

Developing tools that help understand and mitigate collisions could also have implications in environmental conservation, for example, in studying and minimizing the impact of collisions at wildlife intersections or transportation networks on ecosystems. The bottom line is that a practical tool for analyzing linear momentum collisions using microcontrollers could have broad implications across a variety of scientific disciplines, improving safety, innovation, and a deeper understanding of physical phenomena. This research has limitations, namely that if this tool is intended for real-time collision analysis, the speed and ability of the microcontroller to process and react to collision data is very important. Processing under tight time constraints can be a challenge. High-end sensors or microcontrollers may increase the overall cost, limiting their accessibility. Sensor drift or inconsistency may affect the effectiveness of the tool.

4. CONCLUSION

Based on the research and development carried out by researchers, conclusions can be drawn regarding the development procedures, quality, feasibility and ideality of the linear momentum collision practical tool with the microcontroller that has been created. According to material experts, the results of testing the linear momentum impact practical equipment with a microcontroller obtained an average value of 3.8 with an ideal percentage of 95%, so that the quality of the practical equipment was included in the very good category. According to media experts, the linear momentum impact practicum tool with a microcontroller got an average score of 3.9 with an ideal percentage of 97.5%, so that the quality of the practicum tool was included in the very good category. Based on a limited test of the linear momentum collision practical tool with a microcontroller, the average value was 3.93 with an ideal percentage of 78.75%, so that the quality of the practical tool was included in the good category. Based on extensive testing of linear momentum collision practical equipment with microcontrollers, an average value of 3.85 was obtained with an ideal percentage of 77%, so that the quality of the practical equipment was included in the good category. Overall, the linear momentum collision practicum tool with a microcontroller is very good with an ideal percentage of 87.06% so it is suitable for use for linear momentum collision practicum. Researchers recommend that for further research to be able to carry out continuous research and innovation in this area, it will make a significant contribution to the development of practical tools for analyzing linear momentum collisions using microcontrollers, making them more accurate, versatile, and applicable in various domains.

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