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Development of Arduino-Based Rotating Wheel as a Physics Learning Media of Circular Motion

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Abstract: Learning media was used to explain the theory and minimize misconceptions. 50% of physics teachers in East Java have difficulty creating learning media of circular motion. Therefore, researchers created an innovation learning media and analyze the perception of physics teachers to Arduino-based "Rotating Wheel" learning media (ABRW). This research used R&D design with a 4-D model. The subjects were 24 physics teachers throughout East Java and 35 students's XII MA Jabal Noer, Sidoarjo. The instruments used the form of teacher and student response questionnaires and material expert validation sheets. The data analysis is the calculation of the average value of validation results. The result from the physics teacher's and student response more than 65.8% and 75% in very positive category and validation more than 85% with a very valid categori. Thus, it was concluded ABRW props are feasible to use as well as learning physics in a circular motion topic.

Keywords: arduino, circular motion topic, learning media.

Abstrak: *Media pembelajaran digunakan untuk menjelaskan teori dan meminimalisir miskonsepsi. 50% guru fisika di Jawa Timur kesulitan membuat media pembelajaran untuk materi gerak melingkar. Oleh karena itu peneliti membuat suatu inovasi media pembelajaran dan menganalisis persepsi guru fisika terhadap media pembelajaran "Rotating Wheel" berbasis Arduino. Penelitian ini menggunakan desain R&D dengan model 4-D. Subjek dalam penelitian ini adalah 24 guru fisika se-Jawa Timur dan 35 siswa kelas XII MA Jabal Noer Sidoarjo. Instrumen yang digunakan dalam penelitian ini berupa angket respon guru dan siswa serta lembar validasi ahli media dan materi. Analisis data adalah perhitungan nilai rata-rata hasil validasi. Hasil respon guru fisika lebih dan murid lebih dari 65,8% dan 75% dalam kategori sangat positif. Hasil validasi rata-rata lebih dari 85% dengan kategori sangat valid. Dengan demikian dapat disimpulkan bahwa alat peraga roda putar berbasis Arduino layak digunakan yang berkaitan dengan materi gerak melingkar.*

Kata kunci: *arduino, gerak melingkar, media pembelajaran.*

▪ INTRODUCTION

Physics is the study of natural phenomena that can be studied through observation, experimentation, and theory (Sari, Sunarno, & Sarwanto, 2018). Students associate physics learning as challenging because it requires conceptual mastery, analyse and solve problems, and mathematical skills (Samudra, Suastra, & Suma, 2014). A solid understanding of physical concepts can assist students in overcoming existing learning difficulties. However, students' ability to solve problems is not always a good indicator of understanding (Volfson, Eshach, & Ben-Abu, 2020). Circular motion is one of the physics topics where students frequently make misconceptions (Firmansyah & Wulandari, 2016). Students frequently make errors in determining the relationship between the radius of two wheels connected by a rope and the angular speed of each rotation (Yolenta et al., 2016). Students have misconceptions about frequency, assuming

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that frequency is directly proportional to travel time (Volfson et al., 2020). Most students have different ideas about circular motion, specifically speed, acceleration, and force (Canlas, 2016). Students are disinterested in physics lessons as a result of the difficulty in understanding the concept of physics, and they do not pay attention to teachers during learning activities (Wahyuni, Bhakti, Mutakin, Agustina, & Astuti, 2021).

Several factors contribute to students' poor learning outcomes in circular motion material. One of them, namely the learning media used by teachers, is less capable of properly explaining circular motion material. The media in the school does not support the learning process in the following ways: inadequate practicum tools, props in the school do not include all physical materials, and the physics laboratories in the school are not used to the fullest extent possible. Facts in the field show that irregular circular motion material is only taught through the medium of package books or two-dimensional images, making it difficult to understand how the circular motion works in real life. Many schools also lack circular motion props as a learning medium. For example, 60 % of schools in Sukabumi and 68 % of schools in East Jakarta (Laksono Prabowo, Sucahyo Jurusan Fisika, & Matematika dan Ilmu Pengetahuan Alam, 2018). The results of research conducted by (Desy & Desnita, 2015) in 14 laboratories in Jakarta mentioned that most schools already have props for circular motion material but, it is simple and manual. As many as 40% of the sample number from the study showed learning on circular motion material using only the power point slide media. The use of such media certainly has not been able to maximize students' ability to understand circular motion material.

The use of learning media is becoming a solution for fostering students' learning interests, particularly in physics lessons (Richtberg & Girwidz, 2019). Learning media is a teaching tool in the delivery of materials, increasing creativity so that students are motivated to learn. (Tafonao, 2018). Learning media can be used as a practicum tool to help with the learning process. Experiment activities provide valuable experience for students, and practice science process skills (Hidayat & Handhika, 2018). Furthermore, learning media is a component that is coupled with other components in order to establish expected learning scenarios, reduce the occurrence of verbalism troubles, enhance learning stimulus in learning activities, minimize learner misunderstandings towards teacher explanations, and so on. Considering students' limitation, providing strong correlation between students and their environment, generating uniform observation, encouraging and stimulating children to learn (Adi Widodo, 2018).

Microcontrollers began to be used in the production of learning media as technology advanced (Indrasari, Budi, & Fadilla, 2021). A microcontroller is a chip that manages a program that is linked to an electronic device (12). The primary device for controlling and processing the entire system is the Arduino microcontroller (Yusro, Pratama, Maduretno, & Hudha, 2019). Arduino is a microcontroller platform that includes simple hardware and software (Kotseva, Gaydarova, Angelov, & Hoxha, 2019). Through the overview of Arduino, it is now possible to actually equip a laboratory with appropriate devices that allow each student to conduct a series of experiments and measurements with a minimum cost. Nevertheless, understanding the concepts of Arduino requires the learning of some programming experience, and the product's open - source nature fosters cooperative learning (Organtini, 2018). Arduino is

popular in physics experiments because it is inexpensive, flexible, simple to implement, and allows for rapid data collection (Sari & Kirindi, 2019). The use of Arduino in physics experiments includes dynamic fluid material pitot tube props and venturimeters (Herdayanti, Rahmatsyah, & Manurung, 2020), static fluid viscosity materials that are related to the use of ICT. (Sandjaja et al., 2020).

The relationship of the wheels is one example of an application to irregular circular motion. The relationship of the wheels is divided into three parts: the relationship of the central wheels, the relationship of the intersecting wheels, and the relationship of the rope-connected wheels. In this study, a learning medium was developed that presents the concept of the relationship of wheels connected with ropes, such as on the front and rear gears of a bike, where when the front and rear gears are rotated clockwise in a certain time interval, both wheels travel the same length of track. Thus, it can be concluded that the linear speed of both wheels is the same (or). $v_1=v_2$ $\omega_1 R_1=\omega_2 R_2$. This research aims to, analyze the perception of high school physics teachers in East Java regarding the learning media "Arduino-based Rotating Wheels Learning Media".

▪ METHOD

This research was carried out in June-July 2022 using design R&D (Research and Development) using a 4-D model (Define-Design-Develop-Disseminate) developed by Thiagarajan, 1974. The scheme or flow diagram of the study conducted by the researcher is depicted in figure 1. The subjects of this study were 24 physics teachers throughout East Java (in preliminary research) and 35 students of class XII MA Jabal Noer, Sidoarjo (for trial and implementation). The instruments used in this study were in the form of teacher response questionnaires, media expert validation sheets, material expert validation sheets, and student response questionnaires.

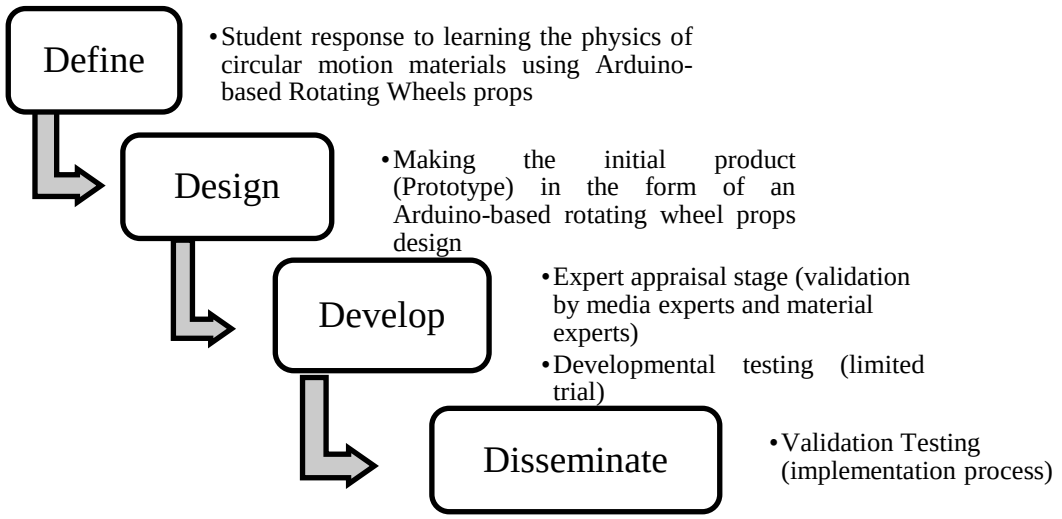

Figure 1. Research scheme

The initial stage (preliminary research) is in the form of a process of distributing teacher response questionnaires that have been validated by two experts for the validity of content and constructs. The validation results showed that the response questionnaire was very valid (average score 3.7 on a scale of 4) and valid for teacher responses. For closed questions on the questionnaire, validity and reliability were analyzed using SPSS 25 assisted product-moment correlation.

Table 1. Validity analysis results

Statement	Cronbach's Alpha	Validity
Physics Learning Fluently	0.734	Valid
There are problems in physics learning	0.658	Valid
Need stimulation for learning physics	0.621	Valid
Need learning media	0.723	Valid

Based on the results of the correlation analysis, if crobach's Alpha value for each item > rtable then the questionnaire is valid. In this study N=35 then the value of rtable= 0.325. So it can be said that the value of Cronbach's Alpha for each item > the value of rtable and questionnaire used in the study is valid. In table 2, the value of Cronbach's Alpha > 0.6, so the questionnaire used in this study is reliable.

Table 2. Reliability analysis results

Cronbach's Alpha	Cronbach's Alpha based on standardized Items	N-of items
0.657	0.672	4

The data analysis technique used in this study is the calculation of the average value of validation results. The average score obtained is then converted into a percentage to obtain the criteria for the validity of the learning medium. Each component has gone through the validation stage by physics teachers and lecturers. The validity criteria are grouped as in Table 4.

Table 4. Validity criteria

Percentage Interval	Interpretation Criteria
0% - 20%	Invalid
21% - 40%	Less valid
41% - 60%	Quite valid
61% - 80%	Valid
81% - 100%	Very valid

Table 5. Physics teacher's and student responds criteria

Range	Criteria
$80\% \leq a < 100\%$	Very Positive
$60\% \leq a < 80\%$	Positive
$40\% \leq a < 60\%$	Quite positf
$20\% \leq a < 40\%$	Less positive
$Na < 20\%$	Very less positive

▪ RESULT AND DISSCUSSION

Define Stage

The purpose of this study was to develop Arduino-based props for circular motion materials. The define stage is needed to know what is needed in developing props. This stage was carried out with preliminary research through the analysis of the responses of physics teachers throughout East Java. Table 6 shows some teacher responses regarding the use of Arduino-based Rotating Wheels learning media in physics learning.

Table 6. Physics teacher's response to the use of arduino-based rotating wheels learning media in physics learning

No.	Statement	Score
1	Arduino-based Rotating Wheels learning media is easy to use	70.0%
2	Arduino-based Rotating Wheels learning media is easy to store and practical	65. 8%
3	Arduino-based Rotating Wheels learning media can motivate students to learn circular motion materials, particularly the concept of wheels connected by ropes.	74.8%
4	Student process skills can be trained through practicum activities using Arduino-based Rotating Wheels learning media	78.3%
5	Arduino-based Rotating Wheels props can help students to visualize circular motion material, the concept of wheels connected by ropes.	81.5%
6	The use of Arduino-based Rotating Wheels props is able to train cooperative attitudes between students.	75.1%
7	The motion topic, the concept of wheels connected with ropes visualized by Arduino-based Rotating Wheels learning media is correct.	84. 2%
	Average	75,67%

In table 6. The score produced in each statement has a dominant percentage with a value above 70%. The statement has a positive category and is very positive. In this study, the highest percentage of physics teacher responses was in the statement "The motion topic, the concept of wheels connected with ropes visualized by Arduino-based Rotating Wheels learning media is correct." with a percentage gain of 84.2%. It can be concluded that for Arduino-based Rotating Wheels learning media is appropriately used in circular motion material on the concept of wheels. Based on the results of the response questionnaire it can be known that props can help students visualize the subject matter. This is in line with the statement "Arduino-based Rotating Wheels props can help students to visualize circular motion material, the concept of wheels connected by ropes", with a score of 81.5% which is very positive category. The use of learning media can train the management of the science process (Iswanto et al., 2021), problem-solving skills (Pratiwi & Fatmaryanti, 2020), improve students' critical thinking skills or HOTS (Dasilva et al., 2019). The lowest percentage of responses is in the statement "Arduino-based Rotating Wheels learning media is easy to store and practical" which is 65.8%. Arduino-based Rotating Wheels learning media is equipped with a usage manual, worksheet for students. The lack of this learning media does not yet have a storage box so it is difficult to carry and requires special shelves to store it.

Some of the respondents' comments regarding Arduino-based Rotating Wheels learning media: "*Props only display the phenomenon of two wheels connected by ropes,*

even more perfect when equipped with the phenomenon of a central wheel and a tangling wheel." Moreover, other comment *"It would be better if this tool is made portable, so it is easy to carry"*. Other comments towards learning media: *"The tools developed are good enough and can be applied to learning so that students will more easily understand the concept of material if using props."*

Design Stage

In the development of Arduino-based rotating wheel props, researchers focused on the selection of designs and supporting components. The framework for design includes the initial design of the product, the layout of the components, and the form of the learning medium.

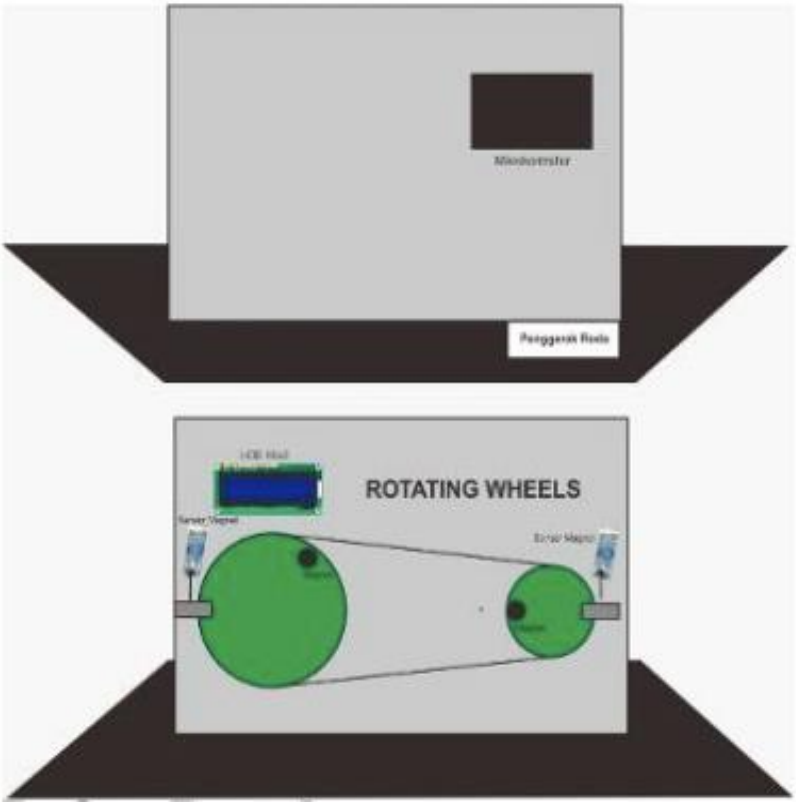

Figure 2. Arduino-based rotating wheel props

Develop Stage

Props that have been developed by researchers are then tested for validity. so that the tool is valid and can be used as a learning medium in circular motion materials. The validity test is divided into two, namely validation by media experts and material experts including four high school physics teachers and two physics education lecturers. Table 7 shows the validation results for Ardunio-based rotating wheels props.

Table 7. Validation results

Component	High School Physics Teacher				Expert Lecturer		Average	Criteria
	1	2	3	4	1	2		
Conformity of Contents and concepts	95%	93%	92%	95%	94%	94%	93.8%	Very Valid
Accuracy	90%	89%	91%	92%	90%	90%	90.3%	Very Valid
Efficiency	85%	86%	88%	89%	87%	87%	87%	Very Valid
Efficiency	89%	87%	88%	87%	86%	87%	87.3%	Very Valid
Fittings of tools	90%	90%	92%	91%	92%	91%	91%	Very Valid

Table 7 shows that the average validation result is more than 85% in components of content and concept conformity, accuracy, efficiency, aesthetics, and completeness of tools. So, it can be said that Arduino-based rotating wheels props are feasible to use with very valid criteria based on table 4.

Disseminate Stage

The next stage is a limited trial, research data on students' responses to learning the physics of circular motion materials using Arduino-based Rotating Wheels props can be seen in table 5.

Table 8. Student response to learning physics of circular motion topic using arduino-based rotating wheels prop

No	Statement	Score
1	Learning physics using Arduino-based props is useful to add to my insights.	80%
2	The information inside th Arduino-based props is easy to understand	75.5%
3	After I finished using the Arduino-based props, I felt that I mastered the circular motion material, especially the connection of the wheels connected by the rope.	78.5%
4	Arduino-based props learning media motivated me to study circular motion material.	82.3%
5	Arduino-based props learning media motivated me to actively discuss in groups.	81.5%
6	Arduino-based props learning media added to my curiosity in studying circular motion material.	83.1%
7	Arduino-based props learning media makes me active in asking if there is material that is not yet understood.	81.5%
8	Arduino-based props learning media helped me answer questions from teachers well.	84.6%

In table 8, the percentage value of each number has a result above 75% which means that each number in the student response questionnaire is categorized as positive and very positive. Based on the student response questionnaire, it can be seen that

learning physics in circular motion topic using Arduino-based Rotating Wheels props can motivate students and help students to solve problems related to circular motion material. The use of learning media encourages changes in students' attitudes and behaviors that are creative and dynamic. Media plays a role in conveying messages from teachers to students that can be used in problem solving in the learning process (Untara, Gustina, & Paramita, 2021).

Props can be used to practice several skills including observing, asking questions, formulating problems, making hypotheses, interpreting data, drawing conclusions, and communication (Eveline, Ardiyati, & Dasilva, 2019). In this study, the highest percentage of student responses was found in the statement of Arduino-based teaching aids learning media helping me answer questions from teachers well with a percentage of 84.6%. It was concluded that students were helped by the presence of Arduino-based Rotating Wheels props. Student activity and student learning outcomes can be improved through the use of interesting learning media and constructivist learning (Maulidiani Rahma, Arief Taqwa, & Adi Pramono, 2020). Students can also add insight and be more active in asking if there is material that is not yet understood, this is known with a student response of more than 80%. Percentage the lowest student response in statement number 2 with a percentage of 71.5% related to information on Arduino-based Rotating Wheels props.

In addition to the results of student responses in providing responses using a likert scale related to the learning that has been carried out, comments, criticisms, and suggestions are also provided. As for some student comments: "*Physics learning is easy to understand when it's more practice than it doesn't practice."*, Other comment: *"This kind of learning is very fun and not boring."*. Moreover, other comment: *"With these kinds of learning I can understand the material easily. "*

▪ CONCLUSION

The majority of respondents from 24 East Java teachers used learning media because it helped students avoid misconceptions. Teachers use learning media to convey physics-related information. Respondents used four types of media, beginning with media props and progressing to video learning, slide ppt, and virtual simulation. Props and video props are two commonly used mediums. In addition to reducing misconceptions, learning media derived from physical matter can improve learners' critical thinking skills. 50% of respondents find it difficult to use media in physical learning, particularly circular motion material. Respondents can help their students understand more by using Arduino-based circular motion learning media.

The result of the physics teacher's response to the use of Arduino-based Rotating Wheels learning media in physics learning has positive and very positive results with a percentage of more than 65.8%. The results of the validation carried out by media experts and material experts, namely high school teachers and lecturers resulted in an average validation of more than 85% with a very valid category. Then, the result of student response to learning physics of circular motion topic using Arduino-based Rotating Wheels Prop has a positive and very positive category with a result above 75%. Thus, it was concluded that Arduino-based rotating wheels props are feasible to use as well as learning physics in a circular motion topic using Arduino-based Rotating

Wheels props can motivate students and help students to solve problems related to circular motion material.

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