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Validation of Educational Robotic-Based Circular Motion Kinematics Learning Module to Improve Critical Thinking Skills with a Guided Inquiry Model for High School Students in Class XI

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Abstrak

Penelitian ini bertujuan mengembangkan dan memvalidasi modul pembelajaran berbasis educational robotic pada materi kinematika gerak melingkar untuk meningkatkan kemampuan berpikir kritis siswa SMA kelas XI. Pengembangan dilakukan menggunakan model ADDIE yang difokuskan hingga tahap pengembangan. Modul dirancang berdasarkan analisis kebutuhan siswa, analisis kurikulum merdeka, serta integrasi media robotik dengan model pembelajaran inkuiri terbimbing. Kegiatan pembelajaran dalam modul disusun berdasarkan sintaks inkuiri terbimbing dan melibatkan aktivitas eksperimen langsung dengan robot edukasi. Subjek penelitian meliputi guru fisika, ahli materi, dan ahli media. Data dikumpulkan melalui wawancara, diskusi kelompok terfokus (FGD), serta angket validasi. Instrumen validasi terdiri dari 26 butir untuk ahli materi dan 20 butir untuk ahli media. Hasil validasi menunjukkan bahwa modul memperoleh skor validasi sebesar 88,96% dari ahli materi 1, 91,35% dari ahli materi 2, dan 91,25% dari ahli media, yang semuanya berada dalam kategori "sangat valid". Dengan demikian, modul pembelajaran ini dinyatakan layak untuk digunakan dalam proses pembelajaran fisika di sekolah. Modul ini juga diharapkan mampu memfasilitasi pembelajaran yang bermakna dan kontekstual, serta membantu siswa menguasai konsep gerak melingkar secara konkret melalui aktivitas robotik yang interaktif.

Kata Kunci: Model ADDIE; *Educational Robotic*; Modul Pembelajaran Kinematika Gerak Melingkar; Inkuiri Terbimbing; Berpikir Kritis

Abstract

This research aims to develop and validate an educational robotic-based learning module on circular motion kinematics material to improve the critical thinking skills of high school students in grade XI. Development was carried out using the ADDIE model which was focused up to the development stage. The module is designed based on student needs analysis, independent curriculum analysis, and integration of robotic media with guided inquiry learning models. The learning activities in the module are structured based on the syntax of guided inquiry and involve hands-on experimental activities with educational robots. The research subjects include physics teachers, material experts, and media experts. Data were collected through interviews, focus group discussions (FGDs), and validation questionnaires. The validation instrument consists of 26 items for subject matter experts and 20 items for media experts. The validation results showed that the module obtained a validation score of 88.96% from subject matter expert 1, 91.35% from subject matter expert 2, and 91.25% from media expert, all of which were in the "very valid" category. Thus, this learning module is declared feasible for use in the physics learning process in schools. This module is also expected to be able to facilitate meaningful and contextual learning, as well as help students master the concept of circular motion in concrete terms through interactive robotic activities.

Keywords*:* ADDIE Model; *Educational Robotic*; Vector Learning Modules; Structured Inquiry; Computational Thinking

Introduction

Physics is a branch of science that studies physical matter, sharing facts, and various concepts. Circular motion is one of the physics materials that has an important role in daily activities (Sunarti & Rusilowati, 2021). Circular motion material is also part of motion kinematics which includes physical concepts. This concept includes various important aspects such as angular velocity, linear velocity, and centripetal acceleration which are interrelated to be able to understand the motion of an object on a circular trajectory (Suswati et al., 2015). The basic competencies of performing circular motions are often difficult for students to understand (Gulo, 2018). One of the reasons is that the learning media used is less effective in explaining the material, and is usually only taught through textbooks or pictures. So that it is difficult for students to understand the concept of circular motion in concrete terms and this can have an impact on students' critical thinking skills (Sya'roni et al., 2021).

Based on the results of interviews that have been conducted with physics teachers at Xaverius 1 Jambi High School, there are several problems in physics learning, including low learning motivation and lack of students' ability to solve calculation problems involving formulas. As a result, it can have a negative impact on students' critical thinking skills, as students who are less motivated tend to be inactive in exploring concepts, asking questions, and looking for deeper solutions which ultimately leads to limited development of critical thinking skills.

In line with these problems, previous researchers have made efforts to improve students' critical thinking skills. Novita et al (2021) stated that the Make A Match learning model has a positive effect on students' critical thinking skills on circular motion materials, because this model encourages active involvement of students in solving problems. In addition, previous researchers also recommended the use of learning media to support the improvement of critical thinking skills, such as the application of HOTS-oriented Student Worksheets (LKS) in the framework of guided inquiry, which has been proven to be able to provide a significant improvement in students' high-level thinking skills (Pratama et al., 2020).

The solutions offered by previous researchers still have shortcomings. The application of the Make A Match learning model tends to focus more on mastering the material by memorization and takes a long time if the preparation is not done optimally (Prihatiningsih & Setyanigtyas, 2018). In addition, the use of Student Worksheets (LKS) also has drawbacks, such as a lack of guidance and direct feedback on parts that are difficult to understand. LKS also often demands complex answers and requires a certain initial understanding. As a result, students who do not have basic knowledge can have difficulty understanding the content of the worksheet (Kurnia et al., 2021).

Referring to the problems and analysis of the shortcomings of previous research, the researcher designed an alternative solution, namely developing an educational robotic-based learning module with a guided inquiry model. This development was carried out to answer challenges in learning physics, especially in the kinematics material of circular motion, which is often considered abstract and difficult to understand by students. In addition, this development is also aimed at providing the potential to improve students' critical thinking skills.

The development of modules was chosen because modules have several advantages in their characteristics. According to Iskandar et al., 2022 The characteristics of the module include being able to make students learn independently (self instructional), presenting material in its entirety in one module (self contained), can be used without depending on other media (stand alone), is able to adapt to the development of science and technology (adaptive), and is easy to use and user-friendly.

The module is developed by integrating educational robotics and using a guided inquiry learning model. The use of robots as a learning medium allows students to understand concepts in a more concrete way, by seeing their application directly through real physical objects (Rahmawati Maulidiyah & Anistyasari, 2020). Meanwhile, the advantage of the guided inquiry model is that it places students as the main subject in the learning process. This model encourages active involvement of learners in every learning activity (Skin et al., 2018). And teachers continue to provide direction in every activity that students do. Thus, students who think more slowly or have a lower level of intelligence can still participate in activities, while students who have high thinking skills do not dominate learning activities (Hosnah et al., 2017).

Overall, the development of robotic-based learning modules using a guided inquiry learning model encourages students to be directly involved in problem solving. This process is expected to improve critical thinking skills as students must identify problems, design strategies, and evaluate the effectiveness of the solutions made. In addition, the development of this module is expected to facilitate high school students in grade XI to master the concept of circular motion more thoroughly and practically.

Problem Formulation

Based on the above background, the formulation of the problem in this study is as follows:

1. What is the process of developing a circular motion kinematics learning module based on educational robotics to improve students' critical thinking skills with a guided inquiry learning model?
2. What are the results of the validation of material experts and media experts on the circular motion kinematics learning module based on educational robotics to improve students' critical thinking skills with a guided inquiry learning model?

Research Objectives

Based on the formulation of the problem above, the objectives of the research are as follows:

1. Explain the stages and processes of developing circular motion kinematics learning modules based on educational robotics to improve students' critical thinking skills with a guided inquiry learning model.
2. Analyzing the validation of material and media experts regarding the educational robotic-based circular motion kinematics learning module to improve students' critical thinking skills with a guided inquiry learning model.

Research Benefits

This research is expected to provide theoretical and practical benefits, namely the following:

Theoretical Benefits

This research is expected to provide information and become one of the sources or references for scientific studies in the field of development of robotic-based learning modules.

Practical Benefits

For teachers: The results of the research in the form of a circular motion kinematics learning module based on educational robotics are expected to be an alternative learning medium in explaining circular motion kinematics material in a visualized and concrete way.

For schools: The results of the research in the form of a circular motion kinematics learning module based on educational robotics are expected to encourage innovative learning, improve the quality of education and create schools that are adaptive to technological developments.

For researchers: The benefits for researchers are to increase experience, expand insight into technological developments for the world of education and become the basis for further research.

Method

The development model used is the ADDIE development model which consists of the analysis, design, development, implementation, and evaluation stages. In this study, the ADDIE stage was used only until the development stage. The following is a picture of the stages of ADDIE according to (Branch, 2009) that is:

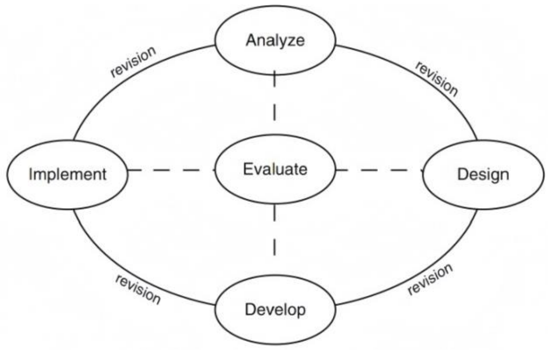

Figure 1. ADDIE Stage

The first stage of this research is the analysis stage, at this stage several analyses are carried out, including needs analysis through the interview process with teachers, literature analysis, curriculum analysis, and material analysis. Literature analysis aims to find out related research topics that are relevant to the research being conducted. Curriculum analysis is carried out to be able to find out the learning outcomes that must be achieved by students, while material analysis aims to find out the breadth and depth of the material presented in the module.

The second stage of this research is the design stage. At this stage, the module design is carried out to obtain an initial prototype. Furthermore, the design of the content of the module is carried out by adjusting to the material and learning model. The learning model used is the guided inquiry learning model and the material raised in this study is circular motion kinematics.

The third stage of this research is the development stage. At this stage, module development is carried out, starting from making an initial prototype of the circular motion kinematics learning module based on educational robotics and validation of the module by media experts and material experts for the final results of the developed module.

The research subject at the analysis stage is a physics teacher. For the design stage, the development team as the subject of research and in the development of the research subject, namely media experts and material experts.

The data collection technique at the analysis stage is an unstructured interview. At the design stage, FGD (Focus Group Discussion) techniques are used with the development team. At the development stage, validity tests are conducted by media experts and material experts as a data collection technique.

The data collection instrument at the analysis stage uses an interview sheet containing question points. At the stage of developing the instruments used were in the form of a material expert validation questionnaire consisting of 26 statements and a media expert questionnaire sheet consisting of 20 statements. The questionnaire is created based on the instrument grid. The following are the grid of material expert validation questionnaire instruments and media expert validation questionnaire grid:

Table 1. Subject Matter Expert Validation Grid

No.	Indicator
1.	Conformity of the material description with competency standards (SK) and basic competencies (KD)
2.	Depth of material
3.	Clarity of material presentation
4.	The description of the material description
5.	Material accuracy
6.	Relationship of material to question
7.	Accuracy in the selection of images, animations, and videos
8.	Accuracy of language use
9.	Printers

Source: Putri et al (2020)

Table 2. Media Expert Validation Grid

No.	Indicator
1.	Precision and design fit
	Audio usage
3.	Layout/visual display
4.	Content layout design
5.	Reusability
6.	Interaktif
7.	*Self Instructional*
8.	*Self Contained*
9.	*Stand Alone*
10.	*Adaptive*
11.	*User Friendly*

Source: Putri et al (2020)

Data analysis techniques at the analysis stage use thematic analysis. This analysis is considered effective for research that requires an in-depth and detailed analysis of the data to uncover important themes that emerge (Rozali, 2022). At the development stage, the data analysis technique uses quantitative with quantitative descriptive analysis techniques. The scores given by subject matter experts and media experts are evaluated using average and percentage calculations. The validation results are used to determine that the module is valid or still needs improvement.

Result and Discussion

Stages of Analysis

In the first analysis stage, the first analysis was an analysis of student needs with interviews with physics teachers of Xaverius 1 Jambi High School. The results of the interview were that there was a lack of student motivation in learning and a lack of students' ability to solve calculation problems involving formulas. Then a curriculum analysis was carried out, the result of this analysis was that the schools that were the research objectives used an independent curriculum. This independent curriculum requires students to be given the foundation of knowledge and skills in responding to the reality of the industrial revolution 4.0, this is relevant as a foundation because the use of educational robotics integrates technology in learning.

Based on the results of the analysis above, the circular motion kinematics learning module based on educational robotics with a guided inquiry model is expected to be a solution to this problem. The development of this module has been adjusted to the curriculum outcomes and integrated with robotics.

Design Stage

This design stage is carried out to design the module design including the module structure and the content of the module. The following is a table of design design, structure and module contents:

Table 3. Table of Structure and Content of the Module

Module Structure and Content	
Module identity	
Foreword	
Table of contents	
Instructions	• Introduction • Introduction to Roblock • Introduction to mBlock programming • Programming algorithms

	• Example questions • Concept Map
Frequency and Period	• Activity 1 • Material • Critical Thinking Test
Mileage	• Activity 2 • Material • Critical Thinking Test
Angular Speed	• Activity 3 • Material • Critical Thinking Test
Linear Speed	• Activity 4 • Material • Critical Thinking Test
Angular acceleration	• Activity 5 • Material • Critical Thinking Test
Linear acceleration	• Activity 6 • Material • Critical Thinking Test
Regular Circular Motion (GMB)	• Activity 7 • Material • Critical Thinking Test
Regular Changing Circular Motion (GMBB)	• Activity 8 • Material • Critical Thinking Test
Bibliography	

At this stage, we also design activities by adjusting the learning model used. The learning model used is the guided inquiry learning model. The syntax of guided inquiry learning can be seen in the following table:

Table 4. Guided Inquiry Syntax

Yes	Sintak (Steps)	Activities
1.	Presenting a Question or Problem	The activity explores students' initial knowledge through demonstrations, encouraging and stimulating students to express their opinions to their groups.
2.	Formulating a Hypothesis	The activity is to propose provisional answers to the problem and is directed at determining hypotheses that are relevant to the problem and prioritizing the hypothesis that is the priority of the investigation.
3.	Designing Experiments	Design the experiment according to the existing steps and learn the instructions for experiments using robots.
4.	Conduct experiments to obtain information.	Students conducted experiments using robots according to the experimental design.
5.	Collect and analyze data	The activity is to search and collect as much data as possible and analyze the data that has been collected to be able to prove the hypothesis whether it is true or not.
6.	Drawing conclusions	The activity of deducing data that has been grouped and analyzed and conclusions are drawn and then matched with hypotheses

(Adapted from (Wahyuni & Taufik, 2016)

Development Stage

At this stage of development, an initial prototype was made. The final result of the module is in the form of two versions, namely the student module and the teacher module. In the teacher module, the content is made more detailed and there are examples of experiments and answers. The following is a cover of student modules and teacher modules:

Figure 2. Student Module Cover

Figure 3. Teacher Module Cover

The module cover above is a cover of the module that has been validated after revision from media experts and material experts. In addition, there is a content of the material that is also validated by material experts and media experts, where the content has been made in accordance with the learning outcomes and learning objectives of the independent curriculum. Below is an example of robot programming contained in the activities in the module:

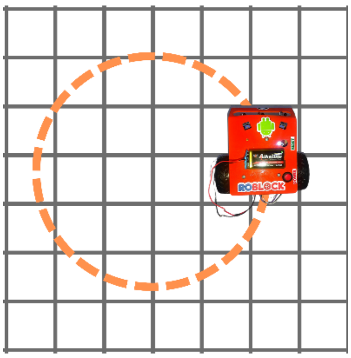

Figure 4. Robot Programming Results

From the example of the robot program in the picture, students are asked to program a circular moving robot. Set a time to complete 1 round, 3 rounds, and 5 rounds at three different speeds: low, medium, and high. Then analyze the relationship between speed and period and frequency based on the data obtained. Then students analyze the problem and design how to program the robot by adjusting the programming algorithm. The following is the programming algorithm of the above problem:

Figure 5. Programming Algorithms

After the module is designed and the initial prototype is produced, then the module is validated by media experts and subject matter experts and there are several revisions. The following are the final validation results from media experts and material experts:

Table 5. Results of Validation of Material Expert Module 1

Validation Stage	Validation results	Criterion
Stage 1	40,38 %	Less Valid
Stage 2	62,50 %	Valid
Stage 3	88,96 %	Highly valid

Table 6. Validation Results of Subject Expert Module 2

Validation Stage	Validation results	Criterion
Stage 1	68,27 %	Valid
Stage 2	77,88 %	Valid
Stage 3	91,35 %	Highly valid

Table 7. Validation Results of the Media Expert Module

Validation Stage	Validation results	Criterion
Stage 1	48,75 %	Quite Valid
Stage 2	91,25 %	Highly Valid

Based on the data of the validation results table above, it can be seen that the validation results of the 1st expert in stage 3 are 88.96%, the validation results of the 2nd subject matter expert in stage 3 are 91.35% and the validation results of the 2nd stage of media experts are 91.25%. . From this percentage, it shows that the module is feasible to use.

Conclusion

This research uses the ADDIE development model which produces a circular motion kinematics learning module based on educational robotics with a guided inquiry learning model to improve students' critical thinking skills. This module has been validated by two subject matter experts and one media expert. The validation results of subject matter expert 1 are 88.96% with very valid criteria, the validation results of subject matter expert 2 are 91.35% with very valid criteria and the results of media expert validation are 91.25% with very valid criteria. Based on the results of validation from the material experts and media experts, the robotic educational-based circular motion kinematics learning module to improve critical thinking skills is suitable for use in research schools.

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Curriculum vitae

The writer is a student of Fiscal Education at the University of Jambi, Indonesia. This research has a focus on the field of educational science and technology. Where the author is directly actively involved in writing along with the development of a circular motion kinematics learning module based on educational robotics using a guided inquiry model to improve students' critical thinking skills that have been aligned with the independent curriculum.