

# Development of a Problem-Based Learning Physics Module on Uniform Circular Motion to Support Students' Critical Thinking Skills

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**Abstract** - Physics instruction on Uniform Circular Motion (UCM) is often perceived by senior high school students as abstract and difficult to comprehend due to its limited connection with real-life phenomena. This study aims to develop a physics teaching module based on Problem-Based Learning (PBL), integrated with simple demonstrations using coins and strings and supported by investigative student worksheets (LKPD). The research employed the Research and Development (R&D) method using a modified ADDIE model consisting of analysis, design, development, and evaluation stages. The study focused on examining the validity and practicality of the developed module. Evaluation was conducted through expert reviews involving three validators (a physics content expert, a pedagogy expert, and an instructional design expert), a one-to-one trial with three students, and a small-group trial with nine Grade XI students from SMAN 13 Palembang. The validation results indicate that the module achieved an average score of 88.33%, categorized as very valid. Meanwhile, the practicality test produced an average score of 91.7%, indicating that the module is very practical to use in learning activities. The module facilitates learning through the PBL stages, including problem orientation, investigation through demonstrations and videos, group discussion, and reflection. Although the effectiveness of the module in improving students' conceptual understanding and critical thinking skills has not yet been empirically tested, the results indicate that the developed module is valid and practical and has the potential to support meaningful learning experiences on the topic of Uniform Circular Motion.

**Keywords:** Problem-Based Learning; Physics Module Development; Uniform Circular Motion; Critical Thinking Skills; Validity and Practicality

## INTRODUCTION

The implementation of the *Merdeka Curriculum* (Independent Curriculum) demands student-centered, contextual, and problem-solving-based learning. In physics education, the topic of Uniform Circular Motion (UCM) is considered particularly challenging for Grade XI senior high school students due to its hierarchical and abstract nature requiring the integration of linear quantities (e.g., linear velocity  $v$ , centripetal acceleration  $a_s$ ) and angular quantities (e.g., angular velocity  $\omega$ , period  $T$ , frequency  $f$ ), as well as analytical skills to connect these concepts to real-world phenomena such as rotating wheels, ceiling fans, or satellites (Dewi et al., 2022).

Based on preliminary observations at SMAN 13 Palembang, many students tend to memorize formulas without fully understanding the underlying physical concepts. For instance, students often find it difficult to explain why linear velocity is always perpendicular to the radius or why centripetal acceleration exists even when the speed of an object remains constant.

Therefore, the development of a learning module based on the Problem-Based Learning (PBL) model is considered an appropriate strategy to facilitate students in constructing their understanding through authentic problems. (e.g., "What happens if the

string breaks while a ball is being swung?”), empirical investigation using simple materials, and collaborative discussion (Akinoglu & Tandogan, 2007; Magdalena, 2020). This module also supports the realization of the *Pancasila Student Profile*: being faithful and pious, critical and creative thinkers, independent, and committed to mutual cooperation.

Research by (Palupi, 2020) demonstrates that PBL effectively enhances critical thinking skills through activities involving problem identification, data collection, and solution evaluation. In line with this module is designed based on the PBL learning stages, which include:

1. Problem orientation through trigger questions related to real-life phenomena
2. Independent and group investigation using simple demonstrations, videos, and student worksheets (LKPD).
3. Development and presentation of solutions through collaborative discussion and presentation.
4. Reflection, where students summarize and evaluate their understanding.

Although previous studies have shown that PBL-based learning materials can improve student engagement and problem-solving skills, the availability of physics learning modules that integrate PBL strategies with simple experimental demonstrations and investigative worksheets for the topic of Uniform Circular Motion is still limited. Therefore, there is a need to develop instructional materials that not only present theoretical explanations but also encourage students to actively investigate physical phenomena through structured problem-based activities.

Therefore, this study aims to develop a physics learning module based on the Problem-Based Learning model for the topic of Uniform Circular Motion and to examine the validity and practicality of the developed

module as a learning resource that has the potential to support students’ critical thinking skills.

## RESEARCH METHODS

This study employed the Research and Development (R&D) method using a modified ADDIE model (Analysis, Design, Development, Implementation, Evaluation), wherein the Implementation phase was conducted only on a limited scale (small group), without large-scale field testing, as the focus was on the module’s validity and practicality (Cahyadi, 2019). Formative evaluation followed (Tessmer, 1993) model and consisted of three stages:

**Table 1.** Three Stages of Development

<b>Expert review</b>	3 validator (material expert, pedagogy, design)	Validation sheet (Likert scale 1–4).	Assessing the suitability of materials, pedagogy, and design
<b>One-to-one</b>	3 students (high, medium, low ability)	Questionnaire + short interview (20 items)	Measuring readability, ease of instructions, potential misconceptions
<b>Small group</b>	9 class XI students of SMAN 13 Palembang	Response questionnaire (20 items) + observation	Measuring practicality in collaborative settings

Data collection was carried out through four stages: (1) unstructured interviews to identify initial learning problems, (2) structured interviews to assess the module’s potential in supporting 21 st-century skills, (3) questionnaire distribution to measure the module’s practicality, and (4) expert validation to evaluate the module’s content and design appropriateness. The

instruments used included interview guides (structured and unstructured), a module validation sheet, and a student response questionnaire. Data analysis employed two main approaches: (1) validity analysis based on expert judgments, and (2) practicality analysis based on student responses from the questionnaire resulting in a module deemed valid, practical, and potentially effective in enhancing students' critical thinking skills. This evaluation approach aligns with principles of instructional development that emphasize the importance of expert validation and formative evaluation in ensuring the quality of educational products (Robert Maribe Branch, 2009). Furthermore, the use of questionnaires and practicality analysis follows the learning evaluation procedures recommended in contemporary development research (Dollinger et al., 2019) Validity data were obtained from expert assessments of the module using a Likert scale, with rating categories as presented in the table.

**Table 2.** Expert Validation Value Categories

No.	Answer Categories	Statement Score
1	Very Suitable	4
2	In accordance	3
3	It is not in accordance with	2
4	Totally Inappropriate	1

The scores obtained from expert assessments were then converted into percentages. This percentage was calculated using the formula below.

$$V = \frac{\sum \text{skor penilaian}}{\text{skor penilaian maksimum}} \quad (1)$$

After the percentage results were obtained, the validity level of the developed module was then categorized according to the product validity criteria shown below.

**Table 3.** Expert Validation Score Category (Wiyono, 2015)

Range	Category
85% < V ≤ 100%	Very Valid
70% < V ≤ 85%	Valid
50% < V ≤ 70%	Less Valid
V ≤ 50%	invalid

Furthermore, data on the practicality of the module was obtained from the results of the student response questionnaire using a Likert scale of 1-4 with criteria as in the following table.

**Table 4.** Student Response Questionnaire Value Categories

No.	Answer Categories	Statement Score
1.	Strongly agree	4
2.	Agree	3
3.	Don't agree	2
4.	Strongly Disagree	1

Subsequently, the module's practicality score was calculated using the following formula:

$$P = \frac{\sum \text{assessment scores}}{\text{maximum possible score}} \quad (2)$$

After the percentage was determined, the practicality level of the developed module was categorized according to the criteria presented in the following table.

**Table 5.** Practicality Category (Wiyono, 2015)

Range	Category
86% ≤ P ≤ 100%	Very Practical
70% ≤ P < 86%	Practical
56% ≤ P < 70%	Less practical
P < 56%	Not practical

## RESULTS AND DISCUSSION

### Results

Relevant prior research also supports the development of this module. For instance, the development of an

interactive e-module based on PBL was found to enhance student learning engagement (Arifin et al., 2024). Similarly, findings indicate that a PBL-based e-module effectively improves students' problem-solving abilities in the topic of static fluids (Yuliani et al., 2025). Furthermore, evidence confirms that PBL implementation is effective in enhancing critical reasoning skills (Asad, 2015). In addition, electronic PBL-based instruction has been shown to significantly improve students' critical thinking skills (S. Dewi & Nisa', 2025), and the use of video-based advance organizers has been demonstrated to improve learning outcomes in Uniform Circular Motion (Lestari et al., 2022).

### 1. Expert Validation Results

The module was validated by three experts using 25 assessment items (maximum total score = 100 per validator). The results are presented in Table 6.

**Table 6.** Expert Validation Results

No	Items	Score	Category
1	Suitability of Material (accuracy, completeness of GMB concepts)	90	very valid
2	Integration of PBL & Pedagogy (syntax, prompting questions, reflection)	85	very valid
3	Learning Design (layout, illustrations, LKPD, assessment)	90	very valid
<b>Average</b>		88,33	very valid

### 2. One-to-One Practicality Test Results

Three students worked on the module + LKPD independently for 30 minutes, then filled out the questionnaire and were interviewed.

**Tabel 7.** One-to-One Results

Items	Score	Category
Ease of Use	88	Very Practical
Language Readability	92	Very Practical
Appearance Attractiveness	87	Very Practical
Compliance with KD	90	Very Practical
<b>Average</b>	89,25	Very Practical

### 3. Small Group Practicality Test Results

Nine students carried out coin-thread demonstration activities, group discussions, and LKPD work during 1 JP.

**Table 8.** Small Group Results

Items	Score	Category
Ease of Use	92	Very Practical
Language Readability	94	Very Practical
Daya Tarik Tampilan	90	Very Practical
Kesesuaian dengan KD	92	Very Practical
<b>Average</b>	92,00	Very Practical

### Discussion

The high validity score (88.33%) indicates that the developed module meets the essential criteria of instructional material quality, including content accuracy, pedagogical suitability, and instructional design. The material aspect received a high score because the module presents the concept of Uniform Circular Motion systematically, starting from basic concepts to applications in

everyday phenomena. In addition, the integration of PBL syntax allows students to explore concepts through problem situations, which aligns with constructivist learning principles. The presence of investigative activities and structured worksheets (LKPD) also supports conceptual understanding by encouraging students to actively analyze physical phenomena rather than merely memorizing formulas.

First, the expert validation score of 88.33% confirms that the content accuracy, the integration of PBL syntax, and the overall instructional design meet the required standards of feasibility. This finding aligns with previous research (Arifin et al., 2024), which demonstrated that PBL-based interactive modules can enhance the quality of learning due to their systematic structure and alignment with students' needs. The integration of PBL components problem orientation, investigation, discussion, and reflection has also been proven to strengthen student engagement and support meaningful knowledge construction (Akinoğlu & Tandoğan, 2007).

The practicality results obtained from the one-to-one and small-group trials indicate that the module is easy to use and understandable for students. This practicality can be attributed to several design features of the module, such as the use of simple experimental demonstrations using coins and strings, which help visualize abstract physics concepts. Furthermore, the inclusion of clear instructions, contextual problems, and step-by-step investigative activities enables students to follow the learning process independently or collaboratively. These features make the module more accessible and engaging for students during the learning process. (Solehah et al., 2023)

In addition, the integration of Problem-Based Learning activities in the module supports the development of students' critical thinking skills. Through problem orientation, investigation, discussion, and reflection stages, students are encouraged to identify problems, analyze information, and propose explanations based on observed phenomena. Such learning processes are consistent with previous studies indicating that PBL-based learning environments can stimulate higher-order thinking and promote deeper conceptual understanding (S. Dewi & Nisa', 2025), which states that the integration of technology and investigative activities within PBL can enhance higher-order thinking skills. The use of visual media such as videos and concrete demonstrations in the Uniform Circular Motion topic has been proven to help reduce misconceptions, as demonstrated by (Lestari et al., 2022), who showed improvements in conceptual understanding through visualization-based media.

Overall, the developed PBL-based module is considered valid, practical, and highly potential for improving students' conceptual understanding and critical thinking skills. Nevertheless, further research with an experimental design is needed to quantitatively test the module's effectiveness, for instance through analyzing learning gains using pretest–posttest measures.

The PBL module enhances student engagement and critical thinking. This is consistent with findings indicating that active, problem-based learning can improve academic achievement and conceptual understanding in science education (Akinoğlu & Tandoğan, 2007). In addition, PBL has also been shown to

improve problem-solving abilities and higher-order reasoning through investigative and collaborative activities, as evidenced by the study of (Solehah et al., 2023). Who developed a PBL-based e-module and found significant improvements in students' science process skills.

## CONCLUSION

This study successfully developed a physics learning module based on the Problem-Based Learning (PBL) model for the topic of Uniform Circular Motion. The validation results indicate that the module achieved a validity score of 88.33%, categorized as very valid, while the practicality test obtained an average score of 91.7%, categorized as very practical. These results suggest that the developed module meets important criteria of instructional material quality, including the suitability of content, the integration of PBL learning stages, and the clarity of instructional design.

The developed module provides meaningful learning support through the integration of simple demonstrations, video analysis, and investigative student worksheets (LKPD). These learning components encourage students to actively explore physical phenomena, participate in discussions, and reflect on their understanding. Therefore, the module has the potential to support student-centered learning and facilitate the development of critical thinking skills in physics learning, particularly in the topic of Uniform Circular Motion.

However, this study focused only on evaluating the validity and practicality of the developed module. Future research is recommended to examine the effectiveness of the module through experimental designs, such as pretest–posttest studies, to measure its impact on students' conceptual

understanding and critical thinking skills more comprehensively.

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