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Development and Validation of a PBL-Based Physics Module Integrating PhET and Local Contexts for Parabolic Motion to Foster Students' Critical Thinking

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Abstract

This study aims to develop a Problem-Based Learning (PBL) based physics teaching module that integrates PhET simulations and local contexts to support students' critical thinking skills in learning about Parabolic Motion. A physics teaching module is defined as a structured resource integrating concept explanations, problem-based activities, simulations, and contextual examples to facilitate self-directed and guided learning. The approach used is research and development based on the ADDIE model, limited to the validation and small-scale implementation stages. The module was validated by three experts and tested through one-on-one and small-group trials involving 10th-grade students. Data collection was conducted using validation sheets, student response questionnaires, and interviews. The results showed that the module achieved a validity level of 88.75% (Highly Valid) and a practicality level of 89.62% (Highly Practical). The novelty of this research lies in the integration of PBL, PhET simulations, and local cultural contexts to produce meaningful learning.

Keywords: Ethnoscience; Parabolic Motion; Critical Thinking Skills; Merdeka Curriculum; Problem-Based Learning; PhET Simulation.

Abstrak

Penelitian ini bertujuan mengembangkan modul pembelajaran fisika berbasis Pembelajaran Berbasis Masalah (PBL) yang mengintegrasikan simulasi PhET dan konteks lokal guna mendukung keterampilan berpikir kritis siswa dalam mempelajari Gerak Parabola. Modul pengajaran fisika didefinisikan sebagai sumber daya terstruktur yang mengintegrasikan penjelasan konsep, aktivitas berbasis masalah, simulasi, dan contoh kontekstual untuk memfasilitasi pembelajaran mandiri dan terbimbing. Pendekatan yang digunakan adalah penelitian dan pengembangan berdasarkan model ADDIE, yang dibatasi pada tahap validasi dan implementasi skala kecil. Modul ini divalidasi oleh tiga ahli dan diuji melalui uji coba satu lawan satu dan kelompok kecil yang melibatkan siswa kelas 10. Pengumpulan data dilakukan menggunakan lembar validasi, kuesioner tanggapan siswa, dan wawancara. Hasil menunjukkan bahwa modul tersebut mencapai tingkat validitas 88,75% (Sangat Valid) dan tingkat kepraktisan 89,62% (Sangat Praktis). Keunikan penelitian ini terletak pada integrasi PBL, simulasi PhET, dan konteks budaya lokal untuk menghasilkan pembelajaran yang bermakna.

Kata kunci: *Etnosains; Gerak Parabola; Kemampuan Berpikir Kritis; Kurikulum Merdeka; Problem-Based Learning; Simulasi PhET.*

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INTRODUCTION

The demands of contemporary skills place Critical Thinking Skills as a fundamental competency that students must possess, especially in science fields such as Physics. Critical Thinking Skills are defined as higher-order thinking skills (HOTS) that involve in-depth analysis, evaluation of evidence, and logical reasoning to arrive at accurate assessments (Agnezi & Rahmah, 2020). In Physics, this skill is crucial for abstract concepts like Parabolic Motion, which requires analyzing velocity and acceleration vectors in two dimensions simultaneously (Widowati et al., 2021). Therefore, strengthening Critical Thinking Skills must be a top priority in the design of Physics learning in accordance with the principles of the Merdeka Curriculum.

In addition to critical thinking skills, physics education in the 21st century also requires the achievement of deep conceptual understanding known as deep learning. The Deep Learning approach in Physics pedagogy is an instructional model that is explicitly developed to foster critical, logical, and structured thinking patterns in line with the objectives of Critical Thinking Skills (Mahulae & Tumanggor, 2025). However, traditional classroom learning often does not fully support the development of Critical Thinking Skills and Deep Learning (Mahulae & Tumanggor, 2025; Ubaidillah et al., 2023). Conventional approaches typically focus on the teacher, resulting in only superficial conceptual understanding (Agnezi & Rahmah, 2020; Widowati et al., 2021). This condition causes students to be less able to connect theory with everyday events. As a result, physics learning becomes less meaningful and does not meet the demands of the 21st century (Pratiwi & Mawardi, 2022).

Conventional approaches often create a gap between theoretical knowledge of Parabolic Motion and students' ability to apply it in everyday contexts. Empirical data shows that tenth-grade students still face significant conceptual difficulties. These difficulties are mainly in correctly distinguishing and integrating motion on the horizontal axis (GLB) and vertical axis (GLBB) (Widowati et al., 2021). Abstract mathematical elements such as trigonometry and vectors further add to the cognitive load for students. As a result, they find it difficult to achieve a comprehensive understanding of parabolic trajectories. Therefore, more contextual, visual, and interactive learning strategies are needed to overcome these problems (Haspen et al., 2021; Pratiwi & Mawardi, 2022).

In response to this issue, various pedagogical approaches have been explored in physics education. Traditional direct instruction and conventional lectures are widely used, but they often emphasize the transmission of knowledge rather than students' active cognitive engagement (Widowati et al., 2021). Student-centered models such as Inquiry-Based Learning and Discovery Learning also show potential in developing critical thinking (Haspen et al., 2021; Jufrida et al., 2023). Nevertheless, these approaches often fail to provide structured guidance for independent learning, especially when students encounter abstract concepts such as Parabolic Motion.

To ensure the consistent and systematic implementation of PBL, the development of physics teaching modules has become an urgent necessity. Unlike independent learning activities, teaching modules provide structured, self-guided instructional resources that lead students through sequential learning experiences, complete with clear objectives, step-by-step support, and assessment tools (Fianti & Neratania, 2024). This structured approach is crucial for the development of critical thinking, as it ensures equal access for all students regardless of their initial ability levels to the cognitive challenges and support needed to build higher-order thinking skills (Saphira & Prahani, 2022). Thus, the development of modules enables the standardized implementation of pedagogical strategies across various classroom contexts.

The Problem-Based Learning (PBL) model is the most appropriate pedagogical framework. PBL is a model specifically designed to initiate the learning process from authentic problems, directly encouraging students to think critically and collaboratively (Bonafide et al., 2021). The PBL syntax, which requires students to examine problems, formulate hypotheses, explore answers, and reflect on decisions, has proven effective in improving critical thinking skills and student learning outcomes (Agnezi & Rahmah, 2020; Hasanah et al., 2021). On the topic of Parabolic Motion, PBL can be implemented through local issues such as the traditional game of pantak lele. This game naturally involves parabolic trajectories and physics aspects such as elevation angle and initial velocity (Musniar et al., 2025). Therefore, PBL is able to bridge abstract concepts with students' real experiences.

Problem-Based Learning (PBL) can be optimized by integrating PhET simulation into the physics learning process, as this method encourages students to actively engage in scientific exploration and evidence-based decision-making (Salazari et al., 2023). PhET offers an interactive virtual experiment platform that allows students to directly observe the dynamic relationships between physics variables such as launch angle, initial velocity, and gravitational acceleration (Banda & Nzabahimana, 2021). This interactive nature not only makes abstract concepts easier to understand, but also reduces students' cognitive load, thereby supporting deeper conceptual understanding (Sweller et al., 2019) . The integration of PBL and PhET has been proven effective in developing critical thinking skills, particularly when examining cause-and-effect relationships and assessing the impact of applying science (Ubaidillah et al., 2023). A study by (Tuhusula et al., 2020) also confirms that integrating both approaches in the topic of Parabolic Motion significantly enhances critical thinking skills among high school students. Therefore, the collaboration between PBL and PhET simulation is a highly recommended learning approach within the Merdeka Curriculum framework, which emphasizes Higher Order Thinking Skills (HOTS) and graduate profile dimensions.

Although much research has been conducted on PBL and PhET simulation (Ubaidillah et al., 2023), teaching tools that integrate these three elements (PBL, local context, and PhET) are still limited, especially those developed based on the principles of the Merdeka Curriculum, which explicitly includes ethical reflection on the application of science (Saphira & Prahani, 2022). Previous studies have often focused separately on simulations or contextual learning, lacking comprehensive integration that addresses cognitive skills and ethical dimensions simultaneously. Therefore, this study aims to fill this gap by developing and testing an integrative teaching module. Specifically, this study addresses the following research questions: (1) What is the level of validity of the PBL-based physics module developed and integrated with PhET and the local context? (2) How practical is the module based on student responses in a limited trial?. Finally, this teaching module also responds to the demands of 21st-century learning, which is contextual, inclusive, and integrated with local wisdom.

METHODS

This study study employs a Research and Development (R&D) approach, utilizing the ADDIE model as its primary framework. However, the scope of the research is limited to the product validation and pilot testing phases, and thus does not include the full implementation phase or a comprehensive evaluation. The research was conducted at MAN 1 Banyuasin during the even semester of the 2023/2024 academic year. The context of the study involved 10th-grade students who had previously studied basic kinematics but had not yet mastered the material on parabolic motion, in order to manage their prior knowledge in a controlled manner. This teaching module is compiled in a comprehensive form and includes elements such as module identity, initial competencies, learning outcomes and objectives, and trigger questions that refer to the local context (pantak lele and rockets). core activities through the *PhET Projectile Motion* virtual experiment, standard and remedial versions of the Student Worksheet, holistic assessment (for, as, and of learning), ethical reflections on the application of physics for humanity, a differentiated approach for students with difficulties in mathematics or basic physics, and teacher guidelines in the form of observation rubrics and assessment instruments.

The research subjects consisted of two main groups: validators and students. Three expert validators were selected based on their respective expertise in physics curriculum, pedagogy, and core subject matter. For the practicality test, students were recruited using purposive sampling. Three students participated in the one-on-one trial, while nine students participated in the small-group trial. These students were grouped based on high, medium, and low academic ability according to their previous physics test scores, so that the feedback obtained reflected the diversity of proficiency levels.

Three main instruments were developed and validated to measure the validity and practicality of the module. Expert Validation Sheet: Expert validation was conducted by three independent experts using a validation sheet in the form of a Likert-scale questionnaire (1–4) with 20 items covering five aspects, namely: (1) content appropriateness, (2) learning approach, (3) assessment strategies, (4) module structure and presentation, and (5) inclusivity and differentiation. This instrument was substantively validated through expert assessment prior to implementation.

Usability Questionnaire: Usability testing was conducted through one-on-one trials with three students of varying abilities using a semi-structured interview guide, followed by small-group trials with nine students via a Likert-scale-based usability questionnaire consisting of 13 closed-ended items and 4 open-ended questions. This instrument assessed three dimensions: (1) content and presentation quality, (2) experience using the PhET simulation, and (3) relevance, reflection, and value of the graduate profile dimensions. Critical Thinking Test: Data on students' critical thinking skills were collected via a 6-item open-ended essay test, where each item was specifically designed to measure one critical thinking indicator: (1) interpretation, (2) analysis, (3) evaluation, (4) inference, (5) explanation, and (6) self-regulation (Hasanah et al., 2022; Saphira & Prahani, 2022).

The module design follows the PBL syntax: (1) orientation towards authentic problems, (2) organization of investigations, (3) guidance of investigations through *PhET simulations*, (4) development and presentation of results, and (5) analysis and evaluation of the problem-solving process. This approach explicitly stimulates critical thinking skills through analytical questions such as: "Why does a 45° angle produce the furthest distance?", "How is the principle of parabolas used to launch aid drones?" or "What are the consequences if this technology is misused?". These questions encourage students to not only understand physics concepts, but also analyze their practical and ethical implications. The teaching module also integrates an ethnoscience context through the traditional game of pantak lele as a trigger problem, in line with the Deep Learning principle that emphasizes cultural relevance (Mahulae & Tumanggor, 2025). Additionally, *PhET simulation* are used to visualize the relationship between elevation angle, initial velocity, and trajectory, reducing mathematical abstraction and strengthening conceptual understanding (Banda & Nzabahimana, 2021; Tuhusula et al., 2020). The module presentation is designed to be visual and interactive, with colorful vector diagrams, speed component infographics, and step-by-step instructions in remedial worksheets to support students who have difficulty with trigonometry or vector concepts. The closing reflection asks not only "what was learned?" but also "what is this knowledge used for?" linking science with moral responsibility, in line with the graduate profile dimensions of critical thinking, collaboration, and communication.

The development procedure was carried out through the following operational stages: Analysis of learning needs and curriculum requirements; Design of a module framework integrating PBL, PhET, and local context; Creation of an initial module prototype; Validation by three experts followed by revisions; One-on-one pilot testing with three students via interviews; Small-group pilot testing with nine students using a practicality questionnaire and critical thinking tests; and Data evaluation to refine the final product.

Quantitative data from expert validation was analyzed using quantitative descriptive techniques (Sugiyono, 2017) by calculating the percentage of module validity as follows:

$$V = \frac{\sum x}{\sum xi} \times 100\% \quad (1)$$

where V is the module validity percentage, $(\sum x)$ is the total number of expert assessments, and $(\sum xi)$ is the total number of ideal scores. Once the percentage results are known, the validity level of the developed module is then grouped into product validity criteria as shown in Table 1.

Table 1. Criteria for curriculum expert validity, pedagogical expert validity, and subject matter expert validity

No.	Validity Criteria	Level of Validity
1	$85\% < V \leq 100\%$	Very valid
2	$70\% < V \leq 85\%$	Valid
3	$50\% < V \leq 70\%$	less valid
4	$V \leq 50\%$	Invalid

Qualitative data from one-to-one interviews were analyzed thematically to identify patterns of suggestions for improvement, which were then used as the basis for final revisions to the module before it was declared a ready-to-use development product. Data on the practicality of the module were obtained based on the results of student response questionnaires. The practicality score of the module was calculated using equation (2).

$$P = \frac{\sum TSe}{\sum TSh} \times 100\% \quad (2)$$

where (*P*) is the percentage of module practicality, (*TSe*) is the total response score of all students, and (*TSh*) is the maximum possible response score of all students. Once the results are known, they are then grouped into product practicality criteria. The product practicality criteria are presented in Table 2.

Table 2. Product practicality criteria.

No.	Practicality Criteria	Level of Validity
1	$80\% < P \leq 100\%$	Very Practical
2	$60\% < P \leq 80\%$	Practical
3	$40\% < P \leq 60\%$	less practical
4	$20\% < P \leq 40\%$	impractical
5	$0\% < P \leq 20\%$	Very impractical

RESULTS AND DISCUSSION

RESULTS

The validity of the module was validated by three independent experts: an expert in independent curriculum, an expert in pedagogy, and an expert in subject matter (Physics). This multi-expert validation approach is in line with the principles of contemporary teaching tool development, which emphasizes content validity through triangulation of expertise (Abdillah et al., 2025; Setyaningrum et al., 2024). The validation results were analyzed descriptively and quantitatively using a Likert scale (1–4), then converted to a feasibility percentage based on Sugiyono's criteria (Sugiyono, 2017).

Table 3. Recapitulation of Teaching Module Validation Results by Experts

Validator	Maximum score	Score obtained	Percentage
Subject Matter Expert (Physics)	80	72	90,0%
Pedagogical Expert	80	73	91,25%
Curriculum Specialist	80	69	86,25%
Average Total	80	70	88,75%

Based on Table 3, the module obtained an average validity percentage of 88,75%, which falls into the Highly Valid category. Furthermore, the validation results per aspect are shown in the following table:

Table 4: Summary of Validity per Aspect (Average Score from 3 Validators)

Aspect validation	Average score	Percentage
Content Suitability (Curriculum & Competencies)	3,67	91,75%
Learning Approach	3,67	91,75%
Assessment Strategy	3,42	85,50%
Module Structure and Presentation	3,58	89,50%
Inclusivity and Differentiation	3,33	83,25%

After revisions based on expert input, one-to-one trials were conducted with three students with varying abilities. Based on the findings of the interviews, initial revisions were made in the form of adding a glossary, simplifying technical language, and adding icons for instructions on how to use *PhET*. The results of small group trials with nine students are presented in Table 4.

Table 5. Practicality test data analysis

Aspects assessed	Maximum score	Average Score	Percentage	Category
Quality of content and module presentation	20	17,9	89,5%	Very practical
Experience using *PhET simulation*	20	17,9	89,5%	Very practical
Relevance, reflection, and value of graduate profile dimensions	12	10,8	90%	Very practical
Total overall	52	46,6	89,62%	Very practical

DISCUSSION

The Problem-Based Learning (PBL) model is an effective approach for creating active, student-centered learning through the solving of authentic problems in real life (Salazari et al., 2023). Although often applied in vocational education, the PBL principle, which emphasizes the provision of practical problems as a starting point for learning, is also highly relevant to general education, particularly in physics learning. This characteristic encourages active student participation in building conceptual understanding (Bonafide et al., 2021; Hasanah et al., 2021), aligning with the module's objective to develop valid, practical PBL tools that integrate PhET simulations and local contexts to foster critical thinking and ethical reflection per Merdeka Curriculum standards.

Based on the data in Table 3, expert validation of the teaching module showed an average validity percentage of 88,75%, which falls into the Highly Valid category. This indicates that the module has met the eligibility criteria, including the accuracy of physics concepts, conformity with 21st-century pedagogical principles, and alignment with the requirements of the Merdeka Curriculum. Thus, this module is theoretically ready to be implemented in learning activities. These results are in line with a study conducted by (Ubaidillah et al., 2023), which also stated the high feasibility of PBL modules supported by *PhET* on the topic of Parabolic Motion, with an average validity of above 85%.

Based on the data in Table 4, the results of the aspect-by-aspect validation show that the content feasibility aspect achieved a score of 91,75%, which is categorized as highly valid. The module is considered highly valid because its content is aligned with the Learning Outcomes (CP) and measurable learning objectives, and is also relevant to the local context through the application of ethnoscience. For example, the traditional game "*pantak lele*" is used as an initial phenomenon to explore the concept of parabolic motion. The inclusion of local context elements has been proven to improve students' understanding of concepts and their engagement in the learning process (Haspen et al., 2021). Furthermore, the use of ethnoscience elements in physics teaching tools also has a positive impact on students' motivation and understanding of concepts (Rahmi et al., 2024).

The learning approach aspect received an average score of 3,67, equivalent to 91,75%, which falls into the highly valid category. This module applies the PBL model through a series of core activities, ranging from video observation, virtual experiments with *PhET simulation*, to group discussions and reflections. This approach has proven effective in promoting critical thinking, collaboration, and communication skills, as expected in meaningful learning principles. The validators stated that the provoking questions and investigative activities were contextually designed and able to facilitate metacognition.

The assessment strategy aspect scored 85,50% with a highly valid category. The module provides holistic assessments including assessment for learning (through observation of participation), assessment as learning (in the form of reflection and student worksheets), and assessment of learning (in the form of written tests). The instruments are equipped with clear assessment rubrics to observe processes and skills. Research shows that integrated ethnoscience physics teaching modules that also utilize virtual lab media such as *PhET* and structured assessments can increase the effectiveness of learning evaluation (Haspen & Syafriani, 2022). In addition, the availability of remedial strategies on student worksheets demonstrates differentiation efforts, although the validators recommend that alternative assessments for students with special needs be further clarified (S et al., 2025)

The structure and presentation of the module received a score of 89,50% and was categorized as highly valid. The module covers all components and is systematically organized, from the identity, learning objectives, learning activities, to assessments and attachments. The learning flow, which includes an introduction, main content, and conclusion, is designed logically and attractively. The language used is clear and communicative, appropriate for the age level of the learners. The visual presentation is adequate, with the use of infographics and QR codes for access to videos and simulations. Research shows that a well-organized module structure and good visual presentation can improve readability and learning effectiveness (Haspen & Syafriani, 2022). In addition, modules with a clearly structured ethnoscience context have been proven to strengthen student understanding (Jufrida et al., 2023).

The aspects of inclusivity and differentiation scored 83,25% with a valid category. This module was assessed to have taken into account the diversity of students by providing support strategies for students experiencing difficulties, particularly through remedial student worksheets that simplify calculations and provide scaffolding. Alternative activities and assessments for students with special needs have also been prepared. The development of PBL modules is known to increase student participation and attitudes toward science from various backgrounds (Fianti & Neratania, 2024; S et al., 2025). However, there were minor revisions from the validators who recommended that differentiation strategies, especially in assessment, be explained in more detail and operationally to ensure their more effective implementation. After the expert input was addressed, the one-to-one validation process was continued.

In the one-to-one evaluation stage, three students with varying levels of ability were asked to try the teaching module independently. The interview results showed that students were able to understand the basic concepts of parabolic motion, mainly due to the context of the "*pantak lele*" game and the interactive simulation. However, some technical terms such as vectors and elevation angles were still unfamiliar, so simplification and the addition of a glossary were needed. Instructions for using the *PhET simulation* were also considered clear enough, but in practice, students still needed teacher guidance in the initial experiments. These findings are in line with the results of research by (Fianti & Neratania, 2024; Haspen et al., 2021), which highlight that during the individual trial phase, students often encounter language, display, and navigation obstacles that are not identified in the expert validation phase. In addition, the use of interactive simulations such as *PhET* is known to improve conceptual understanding, but requires clear operational guidelines (Jufrida et al., 2023). Based on these findings, initial revisions were made in the form of adding a glossary, simplifying technical terms, and including icons for *PhET* usage instructions. These revisions served as a foundation before the module was tested in the small-group evaluation stage.

Table 5 shows the results of the practicality test analysis from the small group trial involving 9 students, in which the PBL physics teaching module with *PhET simulation* integration and the relevance of the local wisdom context showed a very high level of practicality. In general, the module achieved an average score of 46,6 out of 52 (89,62%), which is categorized as "Very Practical". A recapitulation of each aspect shows that the three main dimensions of the teaching module include (1) content and presentation quality, (2) experience using *PhET simulation*, and (3) relevance, reflection, and graduate profile dimension values, each of which obtained a percentage above 89%, namely 89,5%, 89,5%, and 90,0%. These findings indicate that the module is not only cognitively easy to understand, but also affectively engaging and contextually relevant.

The success of integrating PhET simulation as an interactive medium for visualizing abstract concepts of parabolic motion is consistent with the findings of (Banda & Nzabahimana, 2021), who stated that the use of *PhET simulation* significantly improves students' conceptual understanding and reduces cognitive load when learning abstract physics concepts. They emphasize that interactive simulations can connect symbolic representations and real phenomena, especially in two-dimensional kinematics topics such as Parabolic Motion (Banda & Nzabahimana, 2021). In addition, the use of the local context of the traditional game "*pantak lele*" as an entry point for learning supports the principle of contextual teaching and learning (CTL), which, according to (Haspen et al., 2021), can increase student motivation and engagement because the material is linked to everyday experiences. This is reinforced by the positive responses of students to statements number 4 and 11 in the validation instrument, which indicate that the local cultural context is effective in building the meaning and relevance of physics.

The ethical reflection aspect in science that connects the application of physics principles in technology, such as drones for disaster relief versus weapons, also received positive responses from students. This shows the integration of graduate profile dimensions, especially critical thinking and communication values, as stated by the Ministry of (Kementerian Pendidikan Kebudayaan Riset dan Teknologi, 2024) as the basis for the Merdeka curriculum. The students' responses to statements 12 and 13 indicate that the module successfully raised moral awareness regarding the responsibilities of scientists, as emphasized by (Fianti & Neratania, 2024) that the development of ethnoscience-based physics learning tools within the framework of the Merdeka Curriculum can increase students' active participation and scientific attitudes, including awareness of moral responsibility in the application of science.

Overall, the results of the small group trial confirmed that the module met the criteria of high practicality from the user's perspective, in terms of instructional design, content quality, and social relevance. These findings provide a strong foundation for proceeding to the effectiveness testing or limited field testing stage in the development procedure according to (Plomp & Nieveen, 2013). In addition to quantitative data from the Likert scale, analysis of the open-ended responses from the nine students in the small group trial provides deep insight into how PBL teaching modules can encourage the development of critical thinking skills. Question number 4, "Do you feel that this module helps you understand physics better? Explain!" specifically reveals the higher-order cognitive processes that students go through during learning.

The results of a small group trial (n=9) showed that the PBL module with the integration of *PhET simulation* and the local context of "*pantak lele*" significantly encouraged students' critical thinking skills. From the open-ended responses, 8 out of 9 students (89%) stated that the teaching module helped them analyze cause-and-effect relationships in parabolic motion (e.g., angle vs. distance, velocity vs. height), rather than simply memorizing formulas. These findings are in line with the research by (Agnezi & Rahmah, 2020), which states that the PBL model is effective in improving critical thinking skills through in-depth analysis of scientific phenomena. In addition, 7 students (78%) spontaneously associated the application of physics with ethical responsibility, such as the use of drones for disaster relief versus weapons, demonstrating the ability to evaluate values, which is a key indicator of critical thinking. This is in line with the findings of (Fianti & Neratania, 2024), which state that the development of ethnoscience-based physics teaching tools within the framework of the Merdeka Curriculum can increase students' active participation and scientific attitudes, including awareness of moral responsibility in the application of science within their social and cultural contexts.

Student responses also indicate the emergence of authentic questions arising from the simulation experience, such as: "Why is the distance shorter when the throw is too high?" This demonstrates the problem posing process, which is the basis of PBL. Research by Salazari et al., 2023) confirms that integrating virtual experiments with local contexts within the PBL framework can trigger critical questions from students, which become the starting point for the scientific inquiry process. This finding is reinforced by (Ubaidillah et al., 2023), who found that the combination of interactive simulations and contextual reflection significantly improves students' critical thinking skills compared to conventional learning.

Although it yielded positive findings, this study has several limitations. The sample size for the feasibility test was relatively small (n=9), and this study did not involve large-scale effectiveness testing with a control group. Therefore, claims regarding the module's effectiveness in enhancing critical thinking skills should be interpreted cautiously as potential outcomes rather than definitive empirical evidence. Future research is recommended to use a quasi-experimental design to measure empirical impacts more accurately. Nevertheless, this study contributes to the existing literature through a validated integrated model between ethnoscience and digital simulation within the framework of the Merdeka Curriculum, while also providing a practical reference for physics educators who wish to contextualize abstract concepts. Thus, the module is not only practical in its design (89,62%), but also effective in developing higher-order cognitive skills, in line with the objectives of the Merdeka curriculum and graduate profile dimensions (Kementerian Pendidikan Kebudayaan Riset dan Teknologi, 2024).

CONCLUSION

This study successfully developed a physics teaching module based on Problem Based Learning (PBL) on parabolic motion material that has been tested for validity and practicality. Validation by three experts resulted in an average validity percentage of 88,75%, categorized as Very Valid, thus proving that this module meets theoretical standards. A small group trial involving 9 students obtained a practicality level of 89,62% (Very Practical), indicating that the teaching module is easy to use and well received by users. Qualitative data revealed that the integration of local context, *PhET simulation*, and ethical reflection effectively encouraged students' critical thinking skills, especially in analyzing cause-and-effect relationships (89% of students) and evaluating values ethically (78% of students). The unique contribution of this study lies in the synergistic integration of PBL, PhET simulations, and local cultural contexts to foster meaningful learning within the framework of the Merdeka Curriculum. Referring to these findings, it is recommended to continue the research to the effectiveness testing stage to measure the empirical impact of the teaching module on improving critical thinking skills and understanding of the concept of parabolic motion more accurately. The next stage can be carried out through a quasi-experimental design, such as a pretest-posttest control group design, which compares learning outcomes between the experimental class using the teaching module and the control class applying conventional learning.

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