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# DEVELOPMENT OF A PROJECT-BASED LEARNING MODULE ON LIGHT AND OPTICAL INSTRUMENTS TO ENHANCE STUDENTS' CRITICAL THINKING SKILLS AND CREATIVITY

**Kristin Oktaviani[1]*, Putut Marwoto[2], Siti Wahyuni[3]**
[1,2,3]Magister Pendidikan Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Semarang, Semarang, Indonesia
E-mail: kristinoktaviani.kr@gmail.com[1]*, pmarwoto@mail.unnes.ac.id[2], wahyuni.smg@mail.unnes.ac.id[3]

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**Abstract**

This study aims to describe the development process, examine the validity, analyze user responses (teachers and students), and determine improvements in students' critical thinking skills and creativity through the implementation of a science learning module based on Project-Based Learning (PjBL) integrated with deep learning on the topic of Light and Optical Instruments. This research employed a Research and Development (R&D) approach using a modified ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation stages. The trial participants consisted of 25 eighth-grade students from SMP Negeri 1 Pulau Malan. The findings indicate that: (1) the learning module was successfully developed in accordance with the ADDIE procedure, resulting in a 100-page instructional product; (2) the module met the "Highly Feasible" criteria based on expert validation by subject-matter and media specialists, with an overall mean validity score of 93.13%; (3) teacher and student responses were highly positive (teachers: 94.25%; students: 91.80%), indicating that the module is systematic and effective in supporting conceptual understanding; (4) there was a significant improvement in students' critical thinking skills, as evidenced by an N-Gain score of 0.75 (high category); and (5) students' creativity skills reached a very high category (91.50%) following module implementation, particularly in the dimensions of flexibility and originality, supported by the use of recycled materials in optical instrument projects. This study concludes that the PjBL-based learning module on Light and Optical Instruments is effective as an alternative instructional resource for strengthening students' 21st-century skills.

***Keywords: Critical Thinking, Creativity, Light and Optical Instruments, Learning Module, Project-Based Learning***

## INTRODUCTION

The quality of national education must continuously adapt to societal and technological developments, in line with Ki Hajar Dewantara's educational philosophy of kodrat zaman, which emphasizes that education should respond to the demands of its era. In the context of 21st-century learning, educational practices increasingly focus on the development of higher-order thinking skills, particularly critical thinking and creativity, which constitute essential components of the 4C skills framework. In Indonesia, these competencies are explicitly emphasized in the Kurikulum Merdeka and are positioned as core elements of the Profil Pelajar Pancasila, highlighting their strategic role in shaping adaptive and reflective learners.In science education, critical thinking and creativity are indispensable for enabling students to connect theoretical understanding with real-world applications. Learners are expected to engage in analytical reasoning, problem-solving, and the generation of original ideas through scientific inquiry. However, preliminary observations conducted at SMP Negeri 1 Pulau Malan indicate several persistent challenges. The physics learning modules currently in use remain largely conventional and have not sufficiently integrated project-oriented instructional models. Consequently, classroom learning activities have not yet optimally facilitated the development of students' critical thinking skills and creativity. Project-Based Learning (PjBL)–based instructional modules offer a promising pedagogical alternative to address these limitations, as they are closely aligned with deep learning principles and the demands of 21st-century education. PjBL promotes student-centered learning through authentic projects that encourage inquiry, collaboration, reflection, and knowledge construction. The topic of Light and Optical Instruments is particularly well suited to this approach, as it represents a fundamental

area of physics that lends itself to hands-on experimentation and meaningful real-life applications. A growing body of empirical research has demonstrated the effectiveness of PjBL in enhancing students' creativity and collaborative skills, as well as in fostering reflective learning and facilitating the transfer of conceptual understanding to authentic contexts (Cahyani, 2021; Rohmaniyah & Asih, 2024; Wahyudi et al., 2024; Yanti et al., 2023). Nevertheless, studies that systematically focus on the development, validation, and implementation of PjBL-based science learning modules, particularly those integrating deep learning approaches and simultaneously targeting critical thinking and creativity, remain limited, especially at the junior secondary level in rural or semi-remote educational settings. In response to this gap, the present study seeks to develop and evaluate a Project-Based Learning–based science module on Light and Optical Instruments. The study is designed to examine the development process and validity of the module, analyze teachers' and students' responses to its implementation, and investigate its effectiveness in improving students' critical thinking skills and creativity. By doing so, this research is expected to contribute both theoretically and practically to the advancement of innovative science instruction and the strengthening of 21st-century competencies in secondary education.

## LITERATURE REVIEW

The development of 21st-century education has increasingly emphasized the cultivation of higher-order thinking skills, particularly critical thinking and creativity, as essential competencies for students navigating complex scientific and societal challenges. These skills are widely recognized as core elements of the 4C framework and are closely linked to learners' capacity to analyze problems, generate innovative solutions, and apply knowledge in authentic contexts (González-Pérez & Ramírez-Montoya, 2022; Weng et al., 2022). Within science education, fostering critical thinking and creativity is not merely an instructional goal but a fundamental requirement for meaningful conceptual understanding and scientific literacy. Critical thinking in science learning is commonly defined as the ability to interpret data, evaluate evidence, draw reasoned conclusions, and make informed decisions based on logical analysis (García-Carmona, 2025; Manassero-Mas & Vázquez-Alonso, 2022). Empirical studies have consistently shown that traditional teacher-centered instruction tends to limit students' opportunities to engage in such cognitive processes, resulting in superficial understanding and limited transfer of knowledge (Bhardwaj et al., 2025; Cheng & Ding, 2021). Creativity, meanwhile, is associated with fluency, flexibility, originality, and elaboration in idea generation, all of which are crucial for problem-solving and innovation in scientific contexts (Fernández-Fontecha, 2021; Weiss & Wilhelm, 2022). Despite its importance, creativity remains underdeveloped in many science classrooms due to rigid instructional structures and assessment practices that prioritize factual recall over exploratory learning.

Project-Based Learning (PjBL) has emerged as a pedagogical approach capable of addressing these limitations by situating learning within meaningful projects that require inquiry, collaboration, and reflection. Rooted in constructivist learning theory, PjBL emphasizes active knowledge construction through real-world problem solving, allowing students to integrate conceptual understanding with practical application (Siska et al., 2024). Research has demonstrated that PjBL can significantly enhance students' critical thinking by engaging them in sustained inquiry, evidence-based reasoning, and iterative problem-solving processes (Csanadi et al., 2021; Siverling et al., 2021). Furthermore, PjBL environments have been shown to promote creativity by encouraging learners to explore multiple solutions, experiment with materials, and produce original artifacts (Chang et al., 2022; Fitri et al., 2024; Leasa et al., 2023). In recent years, the integration of deep learning principles within PjBL has gained increasing scholarly attention. Deep learning in education refers to learning experiences that promote conceptual understanding, metacognition, and the transfer of knowledge to novel situations (Drigas et al., 2023). Studies suggest that when PjBL is designed to emphasize depth over breadth, students are more likely to develop reflective thinking skills and long-term conceptual mastery (Retno et al., 2025). However, the effectiveness of deep learning–oriented PjBL is highly dependent on the quality of instructional design, including the structure of learning materials and the scaffolding provided to learners.

Instructional modules play a critical role in supporting the successful implementation of PjBL, particularly in science education. Well-designed modules provide systematic guidance for teachers and students, align learning objectives with assessment strategies, and facilitate coherent learning experiences (Busnawir et al., 2025). Research and Development (R&D) studies employing instructional design models such as ADDIE have demonstrated that validated learning modules can improve learning effectiveness, learner engagement, and instructional consistency (Abuhassna & Alnawajha, 2023; Spatioti et al., 2022). Nevertheless, several studies report that many existing science modules remain content-oriented and lack explicit integration of project-based and deep learning approaches, limiting their potential impact on higher-order thinking skills. The topic of Light and Optical Instruments represents

a critical domain in physics education, as it combines abstract theoretical concepts with tangible real-world applications. Prior research indicates that students often experience conceptual difficulties in this area due to its abstract nature and reliance on mathematical representations (Jäder & Johansson, 2025). Project-based activities involving optical instruments have been shown to improve conceptual understanding by enabling students to visualize phenomena and apply principles through hands-on experimentation (Al-Kamzari & Alias, 2025). However, studies focusing on the systematic development and validation of PjBL-based instructional modules for this topic, particularly at the junior secondary level, remain limited.

Moreover, existing literature reveals several gaps that warrant further investigation. While numerous studies have examined the effectiveness of PjBL in improving either critical thinking or creativity, relatively few have addressed both competencies simultaneously within a single instructional intervention. In addition, research integrating PjBL with deep learning principles through a structured instructional module remains scarce, especially in the context of rural or semi-remote schools where access to innovative learning resources is often constrained. Furthermore, limited attention has been given to user responses, particularly teachers' perceptions, which are crucial for ensuring the practicality and sustainability of instructional innovations. In light of these gaps, the present study seeks to contribute to the existing body of knowledge by developing and validating a Project-Based Learning module on Light and Optical Instruments that integrates deep learning principles and explicitly targets both critical thinking and creativity. By examining the module's development process, validity, user responses, and learning outcomes, this study aims to provide empirical evidence on the effectiveness of PjBL-based instructional modules as alternative learning resources for strengthening students' 21st-century skills.

## METHOD

This study employed a development research approach by adopting a modified ADDIE instructional design model, as adapted from Dick and Carey, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation (Spatioti et al., 2022). This model was selected due to its structured yet flexible framework, which allows for iterative refinement of instructional products based on empirical evidence and expert judgment. During the analysis stage, classroom observations were conducted at SMP Negeri 1 Pulau Malan to identify instructional needs, particularly the need for an innovative science learning module. This stage also involved an initial assessment of students' baseline levels of critical thinking skills and creativity in relation to the topic of Light and Optical Instruments. The findings from this stage served as the foundation for determining learning objectives and instructional strategies. The design stage focused on developing the conceptual framework of the Project-Based Learning (PjBL) module. This process included the formulation of the Learning Objective Flow (Alur Tujuan Pembelajaran), project design, Student Worksheets (Lembar Kerja Peserta Didik), and assessment instruments for measuring critical thinking skills and creativity. The module was systematically structured around three core learning phases, understanding, applying, and reflecting, to ensure alignment with deep learning principles and higher-order cognitive development. In the development stage, the initial draft of the learning module was produced and subsequently subjected to expert validation by subject-matter specialists and media experts. The validation process aimed to assess content accuracy, instructional coherence, visual design, and pedagogical suitability. Revisions were made iteratively based on the validators' feedback until the module met the criteria of "Highly Feasible" for instructional use.

The implementation stage involved a product trial of the developed learning module with 66 eighth-grade students at SMP Negeri 1 Pulau Malan. The study employed a pre-experimental research design, specifically a one-group pretest–posttest design, to examine changes in students' critical thinking skills and creativity following the intervention. The evaluation stage encompassed the analysis of both qualitative and quantitative data to determine the validity, practicality, and effectiveness of the developed module. Data were collected using expert validation sheets for content and media evaluation, response questionnaires completed by two science teachers and 66 students, a critical thinking skills test administered before and after the intervention, and a creativity assessment measured through a project-based rubric. The critical thinking test assessed the dimensions of interpretation, analysis, inference, evaluation, and explanation, while creativity was evaluated based on fluency, flexibility, originality, and elaboration. Data analysis was conducted using both qualitative and quantitative techniques. Qualitative data derived from expert feedback and open-ended questionnaire responses were analyzed descriptively to support module revision and interpretation of findings. Quantitative data from expert validation and user responses were converted into percentage scores to facilitate interpretation and standardization. The average score for each indicator was calculated using the arithmetic mean formula proposed by (Saldaña, 2021):

$$\bar{x}_{indicator} = \frac{\sum R_{respondent}}{N}$$

where $\bar{x}_{indicator}$ represents the mean score for a given indicator, $\sum R_{respondent}$ denotes the total score provided by all respondents, and $N$ refers to the number of respondents. To enhance interpretability, the average indicator scores were subsequently converted into feasibility percentages by comparing them with the ideal maximum score ($S_{max}$). The percentage score was calculated using the following formula:

$$P = \frac{\bar{x}_{indicator}}{\bar{S}_{max}} \times 100\%$$

The resulting percentages were then interpreted according to predefined feasibility criteria, namely Highly Feasible, Feasible, Moderately Feasible, Less Feasible, and Not Feasible. These categories were used to determine the overall quality and instructional suitability of the developed learning module.

## RESULTS AND DISCUSSION

### Product Development Process and Module Validity

The development of the Project-Based Learning (PjBL) science module on the topic of Light and Optical Instruments was carried out systematically through the five stages of the modified ADDIE model, namely Analysis, Design, Development, Implementation, and Evaluation. This structured process ensured that the instructional product was developed in a pedagogically sound, iterative, and evidence-based manner. The final output of this development process is a comprehensive 100-page learning module that consistently applies the core instructional sequence of understanding, applying, and reflecting across all project activities. This structure was intentionally designed to support deep learning by guiding students from conceptual comprehension to practical application and reflective thinking. Following the completion of the development phase, the module underwent a rigorous expert validation process to evaluate its instructional quality and feasibility prior to classroom implementation. Validation was conducted by subject-matter experts and instructional media experts, and revisions were made iteratively in response to their feedback. The results of the expert validation are presented in Table 1.

**Table 1.** Expert Validation Results of the PjBL-Based Science Learning Module

| Indicator | Validation | | | | | Mean (%) | Feasibility Criteria |
|---|---|---|---|---|---|---|---|
| | V1 | V2 | V3 | V4 | V5 | | |
| Content Feasibility | 3.50 | 3.69 | 3.63 | 3.94 | 3.94 | 93.44 | Highly Feasible |
| Presentation Feasibility | 3.60 | 3.60 | 3.53 | 3.80 | 3.87 | 92.00 | Highly Feasible |
| Linguistic Feasibility | 3.75 | 3.38 | 3.63 | 3.38 | 3.88 | 90.00 | Highly Feasible |
| Graphical Feasibility | 3.50 | 3.50 | 3.50 | 3.00 | 4.00 | 87.50 | Highly Feasible |
| Overall Mean (%) | 89.69 | 88.52 | 89.27 | 88.20 | 97.99 | 90.73 | Highly Feasible |

As shown in Table 1, the developed module achieved a high level of feasibility across all validation dimensions. The content feasibility dimension obtained the highest average score (93.44%), indicating strong alignment between learning objectives, scientific accuracy, curriculum standards, and project-based activities. This result suggests that the module content adequately supports students' conceptual understanding of Light and Optical Instruments through meaningful and contextually relevant learning tasks. The presentation feasibility dimension achieved an average score of 92.00%, reflecting the logical organization of instructional components, clarity of learning flow, and coherence between objectives, activities, and assessments. The linguistic feasibility dimension reached an average score of 90.00%, indicating that the language used in the module was clear, communicative, and appropriate for junior secondary students while maintaining academic rigor. Although the graphical feasibility dimension received the lowest average score (87.50%), it still fell within the "Highly Feasible" category, suggesting that the visual design, layout, and use of illustrations were sufficient to support learning, with only minor refinements recommended. Overall, the module obtained a total mean feasibility score of 90.73%, categorizing it as "Highly Feasible." These findings demonstrate that the PjBL-based science module meets established quality standards for instructional materials and is suitable for classroom implementation. The consistently high validation scores across multiple dimensions further indicate that the module was developed through an integrative approach that balances pedagogical substance, instructional clarity, and visual usability. Such validity is essential to ensure that the module not only delivers accurate scientific content but also effectively facilitates project-based learning experiences aimed at enhancing students' critical thinking skills and creativity.

### Teachers' and Students' Responses to the Learning Module

User responses constitute an essential indicator of the practicality and acceptability of an instructional product, as they reflect how the developed module is perceived and experienced by its primary users in authentic classroom settings. In this study, user responses were collected from both teachers and students to evaluate the clarity, usability, and instructional effectiveness of the Project-Based Learning (PjBL)–based science module on Light and Optical Instruments. Teacher responses were obtained through a structured questionnaire completed by three science teachers who were directly involved in the implementation and evaluation of the module. The analysis revealed that the teachers' overall mean response score reached 88.88%, which falls within the "Very High" category. This result indicates that the teachers perceived the module as highly appropriate in terms of content relevance, instructional structure, alignment with learning objectives, and its capacity to support student-centered, project-based learning. High teacher acceptance is particularly important, as teachers play a central role in determining the sustainability and effective integration of instructional innovations in classroom practice. Student responses were collected from 66 eighth-grade students using a readability and usability questionnaire designed to capture learners' perceptions of the module. The results of the student response analysis are summarized in Table 2 and visually illustrated in Figure 1. The findings show that the students' overall response to the module reached an average score of 91.80%, which is categorized as "Very Positive." This high level of student response suggests that the module was well received, easy to understand, and engaging, particularly in facilitating project activities related to Light and Optical Instruments.

**Table 2.** Summary of Teachers' and Students' Responses to the PjBL-Based Learning Module

| Respondent Group | Number of Respondents | Mean Percentage (%) | Response Category |
|---|---|---|---|
| Teachers | 3 | 88.88 | Very High |
| Students | 66 | 91.80 | Very Positive |

As presented in Table 2, both teachers and students demonstrated consistently high levels of acceptance toward the developed module. Students' positive responses can be attributed to the module's systematic presentation, contextual project design, and clear integration of hands-on activities that allowed them to actively engage with abstract physics concepts. Moreover, the readability of the module, indicates that the language, visual layout, and instructional guidance were appropriate for junior secondary students, thereby supporting independent and collaborative learning processes. The convergence of positive responses from both teachers and students provides strong evidence of the module's practical feasibility and instructional usability. These findings align with previous studies suggesting that well-designed PjBL instructional materials enhance learner engagement and instructional effectiveness by fostering meaningful learning experiences (Wahyudi et al., 2024; Yanti et al., 2023). Consequently, the high response scores indicate that the developed module is not only valid in terms of expert judgment but also effective and acceptable from the users' perspective, reinforcing its potential for broader implementation in science education.

### Improvement of Students' Critical Thinking Skills and Creativity

The results of the pretest–posttest analysis indicate a significant improvement in students' critical thinking skills following the implementation of the Project-Based Learning (PjBL) module. As illustrated in Figure 1, the mean posttest score was substantially higher than the mean pretest score, demonstrating the effectiveness of the instructional intervention in enhancing higher-order cognitive skills.

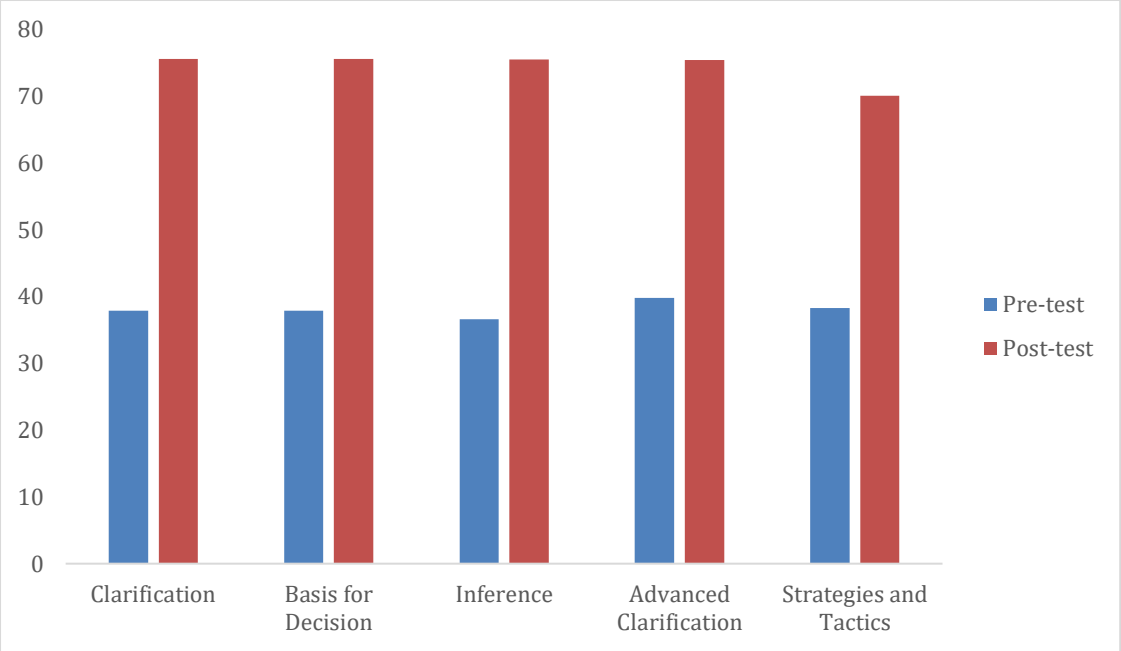


**Figure 1.** Mean Pretest and Posttest Scores of Critical Thinking

In this study, critical thinking skills were conceptualized based on the framework proposed by Pnevmatikos et al. (2023), which comprises five core dimensions: clarification, the bases for a decision, inference, advanced clarification, and supposition and integration. The observed improvement across these dimensions suggests that the PjBL-based module provided meaningful learning experiences that encouraged students to analyze problems, justify decisions, draw logical conclusions, and integrate concepts coherently. The integration of authentic projects related to Light and Optical Instruments enabled students to actively engage with scientific concepts, thereby facilitating deeper cognitive processing and reflective thinking. The improvement in critical thinking skills can be attributed to the core characteristics of PjBL, which emphasize inquiry-based problem solving, evidence-based reasoning, and iterative reflection. These findings are consistent with previous research indicating that project-based instructional approaches are effective in fostering critical thinking by situating learning within real-world contexts and sustained inquiry processes. Consequently, the results confirm that the developed module not only supports conceptual understanding but also strengthens students' analytical and evaluative capacities. In addition to critical thinking, students' creativity skills were assessed through a project-based rubric applied to the products generated during each learning session. Creativity was evaluated across multiple meetings to capture its developmental trajectory throughout the implementation of the module. The average percentage scores of students' creativity achievements for each meeting are presented in Table 3.

**Table 3.** Students' Creativity Achievement Across Learning Sessions

| Learning Session | Mean Score | Category |
|---|---|---|
| First | 75.13 | Very High |
| Second | 74.37 | Very High |
| Third | 74.43 | Very High |
| Fourth | 74.37 | Very High |
| Fifth | 74.56 | Very High |
| Sixth | 75.95 | Very High |
| Seventh | 74.87 | Very High |
| Eighth | 75.79 | Very High |

As shown in Table 3, students' creativity consistently remained within the "Very High" category across all learning sessions. Notably, students demonstrated strong creativity skills from the initial stages of the intervention, with an average score of 75.13 in the first session. This finding indicates that learners entered the learning process with a relatively high level of creative potential. The most pronounced improvement occurred during the sixth session, where the mean creativity score reached 75.95, representing the highest value across all sessions. Although

a slight decline was observed in the seventh session (74.87), the score increased again in the eighth session (75.79), albeit without surpassing the peak achieved in the sixth session. Overall, these results illustrate that students' creativity was not only consistently maintained at a very high level but also exhibited a reinforcing upward pattern, particularly toward the middle and final phases of the learning intervention. The consistently high initial scores suggest that the PjBL-based module functioned not merely as a means of increasing creativity, but also as a mechanism for sustaining and optimizing students' existing creative capacities. By engaging students in hands-on projects, encouraging flexibility in design, and allowing originality in the use of materials, such as recycled components for optical instruments, the module created an environment conducive to creative expression and innovation. Taken together, the findings demonstrate that the developed PjBL-based science module is effective in simultaneously enhancing students' critical thinking skills and maintaining a high level of creativity. These outcomes reinforce the potential of project-based instructional modules as powerful pedagogical tools for strengthening 21st-century skills within junior secondary science education.

## CONCLUSION

This study demonstrates that the development of a Project-Based Learning (PjBL) science module integrated with deep learning on the topic of Light and Optical Instruments effectively addresses the research objectives related to instructional quality, usability, and learning outcomes. Through a systematic Research and Development approach using a modified ADDIE model, the study confirms that a well-structured instructional module grounded in the understanding–applying–reflecting framework can achieve a high level of instructional validity and practical feasibility. The positive responses from both teachers and students indicate that the module is pedagogically coherent, accessible, and supportive of meaningful learning experiences. More importantly, the findings show that the module contributes to a substantive improvement in students' critical thinking skills and consistently maintains creativity at a very high level, suggesting that project-based learning tasks function not only as a mechanism for skill enhancement but also for sustaining and optimizing students' existing creative potential. The novelty of this study lies in its integration of PjBL and deep learning principles within a validated instructional module specifically designed for abstract physics content, thereby offering an empirically grounded alternative learning resource that supports the development of 21st-century skills in junior secondary science education without overstating its generalizability.

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