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PHYSICS TEACHING MATERIALS WITH ETHNO, INQUIRY, AND PROJECT APPROACHES TO IMPROVE MULTIPLE SKILLS OF PROSPECTIVE EDUCATORS

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ABSTRACT

Physics education requires innovative teaching materials to develop essential 21st-century skills such as critical thinking, problem-solving, collaboration, and communication. This research addresses this urgency by developing and evaluating Ethno Inquiry and Project-based physics teaching materials. These materials integrate formal science concepts with ethnoscience, offering a culturally relevant learning experience. This study utilized a Research and Development (R&D) method with a 4D model approach (Define, Design, Develop, and Disseminate) to create and test these materials. Validation from experts showed excellent validity with average scores above 4.6. Field trials involving 40 prospective physics teachers demonstrated significant improvements in critical thinking, problem-solving, collaboration, and communication skills, particularly in problem-solving (36.67%) and collaboration (25.71%). The strong correlation between skills suggests that these materials are effective tools for modern physics education. The implications indicate these teaching materials can be applied in diverse educational settings to enhance essential skills in prospective educators. Further research is recommended to explore their adaptability in various educational contexts.

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1. INTRODUCTION

Physics education plays a crucial role in equipping future educators with essential 21st-century skills, including critical thinking, problem-solving, collaboration, and communication (Aditya et al., 2022). These skills are vital for addressing complex challenges in both educational and professional settings (Pramita et al., 2021). However, traditional teaching methods often fall short of effectively developing these competencies, especially in physics education, which demands a deep conceptual understanding and strong practical application abilities (Martawijaya et al., 2023). To overcome these challenges, innovative teaching materials are required to stimulate higher-order thinking skills and social competencies (Mulhayatiah et al., 2022).

One promising approach to address these challenges is the integration of project-based learning with the ethno-inquiry method. This approach not only aids students in understanding physics concepts but also enhances their creative thinking and problem-solving skills. Project-based learning has been shown to effectively increase student competence by encouraging the development of physics-related products or teaching aids that are then investigated within the learning context (Martawijaya et al., 2023; Juliyanto & Trisnowati, 2021). Additionally, inquiry-based learning is recognized as an effective method for improving student learning outcomes and critical thinking skills. Such materials have successfully increased students' knowledge and skills while motivating them to be more active in the learning process (Lisa, 2023). By integrating inquiry methods into physics education, students are encouraged to think critically and analyze problems in depth, ultimately improving their problem-solving skills (Nisa, 2023; Haryadi & Nurmala, 2021).

The Ethno-STEM approach, which integrates local cultural elements into science education, has also shown promising results in enhancing scientific literacy and students' appreciation of cultural heritage (Sumarni, 2023). This integration not only enriches students' learning experiences but also connects education with cultural contexts, making it more relevant and meaningful. In the context of physics education, the ethno-inquiry approach offers a unique perspective on understanding scientific concepts, helping students become more engaged and motivated in their studies (Hu, 2024). Overall, the combination of project-based learning, guided inquiry, and Ethno-STEM provides a comprehensive solution for enhancing creative thinking, problem-solving, collaboration, and communication skills in physics education. These approaches are expected to create a more dynamic and interactive learning environment that not only supports academic achievement but also develops essential soft skills for future physics educators (Mulhayatiah et al., 2022).

Despite the recognized importance of developing critical thinking, problem-solving, collaboration, and communication skills in physics education, there is still a gap in the implementation of effective teaching methods to achieve these goals. Traditional physics teaching methods often fail to provide the deep and meaningful learning experiences necessary for developing these skills (Martawijaya et al., 2023). Several studies have demonstrated that project-based, inquiry-based, and Ethno-STEM teaching materials can significantly improve students' cognitive and affective skills (Wahyudi, 2023; Herliana, 2023). However, no research has yet comprehensively evaluated the impact of combining these three approaches into a single integrated physics teaching material. Therefore, this study aims to develop and test the effectiveness of physics teaching materials that combine Ethno, Inquiry, and Project approaches to enhance the creative thinking, problem-solving, collaboration, and communication skills of future physics educators.

A review of the literature has identified various approaches for improving students' creative thinking, problem-solving, collaboration, and communication skills. One proven effective method is project-based learning, which focuses on the development of physics products or teaching aids (Martawijaya et al., 2023). Additionally, inquiry-based teaching materials are known to effectively foster higher-order thinking skills such as critical and creative thinking, as well as student motivation (Lisa, 2023). The guided inquiry approach in physics education has been shown to improve students' cognitive skills and conceptual understanding, preparing them better for academic and real-life challenges (Wahyudi, 2023; Herliana, 2023). The Ethno-STEM approach,

which integrates local cultural elements into science education, has shown promising results in improving students' scientific literacy and appreciation of cultural heritage (Sumarni, 2023). This approach enriches students' learning experiences by connecting education with cultural contexts, making it more relevant and meaningful (Hu, 2024). The combination of project-based learning, guided inquiry, and Ethno-STEM offers a comprehensive solution for enhancing creative thinking, problem-solving, collaboration, and communication skills in physics education. The study is anticipated to contribute significantly to preparing future physics educators with the skills needed to face 21st-century educational challenges. The integration of these approaches also provides a strong foundation for developing teaching materials that not only support academic achievement but also enhance the essential soft skills of future educators.

Although research indicates that project-based and inquiry-based approaches can improve students' critical thinking and problem-solving skills, there is still a gap in the implementation of the combined Ethno, Inquiry, and Project approaches in physics teaching (Martawijaya et al., 2023; Sumarni, 2023). Previous research has tended to focus on these approaches separately, necessitating a study that integrates all three approaches to effectively enhance the 4C skills—critical thinking, problem-solving, communication, and collaboration—in the context of physics education.

This study aims to analyze the characteristics, feasibility/kevalidan, and effectiveness of physics teaching materials based on the Ethno, Inquiry, and Project approaches in improving the creative thinking, problem-solving, collaboration, and communication skills of future physics educators. This study will also evaluate the relationship between the use of these teaching materials and the improvement of 4C skills in future educators, which are essential competencies in modern education (Pratiwi, 2024). By combining project-based learning, which has proven effective in enhancing students' practical skills (Martawijaya et al., 2023), inquiry-based learning, which promotes critical thinking skills (Lisa, 2023; Nisa, 2023), and the Ethno-STEM approach, which connects education with cultural contexts (Sumarni, 2023), this study is expected to contribute new insights into the development of holistic and contextual physics teaching materials. The novelty of this research lies in the integration of these three approaches into a single comprehensive teaching material package, which has been little explored in previous literature. The scope of this research includes the development, implementation, and evaluation of these teaching materials in the context of physics education, focusing on improving critical thinking, problem-solving, collaboration, and communication skills. This study will also assess the feasibility of the teaching materials based on user feedback and their effectiveness in enhancing student skills, providing a strong foundation for the adoption of this approach in various educational contexts.

2. METHOD

2.1 Research Design

The Research and Development (R&D) method and the 4D model (Define, Design, Development, and Dissemination) are widely recognized approaches in educational research. According to Gay, Mills, and Airasian (2012), the R&D model focuses on developing educational products through a systematic cycle, which often includes extensive testing and revisions until a desired level of effectiveness is achieved. The 4D model, as referenced in the literature, provides a structured framework for creating teaching materials that aim to enhance the skills of prospective

physics teachers, including creative thinking, problem-solving, collaboration, and communication. Although the complete 4D model includes a dissemination phase, research studies often focus on the initial three phases: Define, Design, and Development, to establish a solid foundation for effective educational tools. Additionally, Creswell (2009) emphasizes the importance of choosing the appropriate research design to align with the study's goals, highlighting that models like the 4D can offer a focused approach to developing educational interventions.

In the Define stage, the research began with the identification of needs and problems through an in-depth literature review and preliminary studies. The main focus was to understand the challenges faced by prospective physics teachers in their teaching practice and to establish the research objective, which was to develop teaching materials that could address these challenges by enhancing multiple skills (Pratama et al., 2021).

The Design stage involved the conceptualization of Ethno, Inquiry, and Project-based teaching materials. During this stage, the researchers designed learning modules, activities, and assessment instruments, including observation, interviews, and questionnaires. This development was based on the findings from the literature review and the needs identified in the previous stage (Indahwati, 2023).

The Development stage encompassed the initial implementation of the designed teaching materials, followed by validation by 10 expert validators, including physics education lecturers and senior physics educators. This validation aimed to ensure the effectiveness and appropriateness of the teaching materials. Following validation, an initial trial was conducted with 40 prospective physics teachers to collect data on the effectiveness of the teaching materials in enhancing creative thinking, problem-solving, collaboration, and communication skills. The results of the trial were used to revise and refine the teaching materials before they were ready for broader dissemination (Wahyudi, 2023; Adawiah, 2024).

2.2 Population and Sample

The population for this study consisted of all students in the physics education program at UIN Raden Fatah Palembang. The sample included 40 third-semester students who were prospective physics educators. The sampling technique used was purposive sampling, which involved selecting subjects considered most representative of the research objectives. The selection of the sample was based on similar academic achievements in fundamental physics courses, ensuring that the findings could be more easily generalized to the broader population (Alexander et al., 2007).

2.3 Research Procedure

The research procedure began with the Define stage, which involved identifying needs and problems and establishing the research objectives. The next stage was Design, where the Ethno, Inquiry, and Project-based teaching materials were conceptualized. This stage included the creation of modules, activities, and assessment instruments. Once the design was completed, the process continued with the Development stage, during which the teaching materials were validated by experts and tested on a small group of students. This process involved revising the teaching materials based on feedback from the trial to produce an optimal product before broader dissemination (Patiño et al., 2023).

2.4 Data Collection Techniques

Data for this study were collected through various methods, including observation, interviews, questionnaires, and documentation. Observations were conducted during the learning process to record interactions, participation, and student responses to the teaching materials. Interviews were conducted to gain deeper insights into students' perceptions and experiences related to the use of the teaching materials. Questionnaires were used to collect quantitative data on the effectiveness of the teaching materials in enhancing multiple skills. Documentation, including academic records and student work, was also collected for further analysis (Lederman, 2012).

2.5 Data Analysis Techniques

The collected data were analyzed using both qualitative and quantitative descriptive analysis techniques. Qualitative descriptive analysis was employed to interpret data from interviews, observations, and documentation, which were then organized into thematic narratives. Quantitative descriptive analysis was used to analyze the questionnaire data and pretest-posttest results, with the aim of evaluating improvements in creative thinking, problem-solving, collaboration, and communication skills.

Additionally, to analyze the relationships between skill variables, Structural Equation Modeling (SEM) was utilized. This analysis began with a normality test using the Liliefors test to ensure that the data were normally distributed. If the data were normally distributed, hypothesis testing was then conducted using SEM to determine the relationships between creative thinking, problem-solving, collaboration, and communication skills (Priyatno, 2012). The analysis was grounded in the hypothesis that creative thinking skills are foundational to problem-solving and communication abilities, influencing them in significant ways. The following hypotheses were tested:

1. Creative thinking skills positively affect problem-solving abilities.
2. Problem-solving skills influence communication skills.
3. Creative thinking skills impact communication skills.
4. Creative thinking skills influence problem-solving abilities.

3. RESULTS AND DISCUSSION

3.1. Result (Finding)

Research Objective 1: Characteristics of Ethno, Inquiry, and Project-Based Physics Teaching Materials

Tabel 3.1. Characteristics of Physics Teaching Materials

No	Study Topic	Science Concepts (Formal Science)	Science Reconstruction	Ethnoscience Context
1	Quantities and Measurements	1. Mass, length, time, and temperature quantities and units.	1. Mass, length, time, and temperature quantities and units.	Patok Lele: The use of patok lele in determining boundaries, distances, areas, and

No	Study Topic	Science Concepts (Formal Science)	Science Reconstruction	Ethnoscience Context
		2. Measurement of mass, length, time, and temperature.	2. Measurement of mass, length, time, and temperature.	positions involving length measurement and traditional units.
2	Linear Motion	Position, distance, displacement, velocity, and acceleration in linear motion.	Analysis of linear motion in everyday activities such as walking, running, or cycling.	Basic movements in pencak silat, such as steps and kicks that follow the pattern of uniform linear motion (ULM).
3	Work and Energy	Work, kinetic energy, potential energy, the law of conservation of energy.	Analysis of work and energy in everyday activities, such as lifting objects and walking.	Traditional boat-making that involves the concepts of work and energy at each step of the process.
4	Momentum and Collision	Concepts of momentum, the law of conservation of momentum, elastic and inelastic collisions.	Analysis of momentum and collisions in everyday activities, such as playing ball and driving.	Karate movements that involve the concepts of momentum and collision in every attack and defense movement.
5	Equilibrium of Rigid Bodies	Concepts of static and dynamic equilibrium, center of mass, and torque.	Analysis of equilibrium in everyday activities, such as standing on one leg or carrying objects on the head.	Traditional game of engklek, which involves body balance in every step and jump.
6	Gravity	Newton's law of gravity, gravitational acceleration, free fall motion.	Analysis of gravity in everyday activities, such as the falling of objects and the bouncing of a ball.	Kite flying, which involves the concept of gravity in every ascent and descent of the kite.
7	Fluid Mechanics	Fluid laws, viscosity, fluid flow, and fluid pressure.	Analysis of fluid mechanics in everyday activities, such as the flow of water and air pressure.	Bamboo gun-making that involves the concepts of air pressure and flow in its usage process.
8	Vibration, Waves, and Sound	Concepts of vibration, waves, frequency, amplitude, and sound.	Analysis of vibration and waves in everyday activities, such as phone vibrations and sound waves.	Gamelan musical instruments that involve the concepts of vibration and waves in producing sound.
9	Pempek Palembang Making	Physics processes in food making.	Analysis of physical changes in the food-making process.	The making of Pempek Palembang, which involves the concepts of physical and chemical changes at each step of the process.

Table 3.1 presents the integration of Ethno-based learning in a first-semester Basic Physics course, linking formal science concepts with practical and ethnoscience contexts. For instance, the concept of measurement in physics is connected to the use of "patok lele" for determining boundaries and distances using traditional units. Linear motion is analyzed through the basic movements in pencak silat, while the concepts of work and energy are illustrated by the process of traditional boat-making. This approach demonstrates how formal science can be reconstructed and applied within local cultural contexts, enhancing students' understanding and relevance of physics concepts through practical applications in everyday life. This integration underscores the importance of contextualizing formal science within local cultural practices, which not only enriches the learning experience but also makes scientific concepts more accessible and relatable to students.

Research Objective 2: Feasibility of Ethno, Inquiry, and Project-Based Physics Teaching Materials

Table 3.2 summarizes the results of the expert validation

Assessment Aspect	Average Score	Category
Content Validity	4.8	Very Good
Construct Validity	4.7	Very Good
Implementation Validity	4.6	Very Good

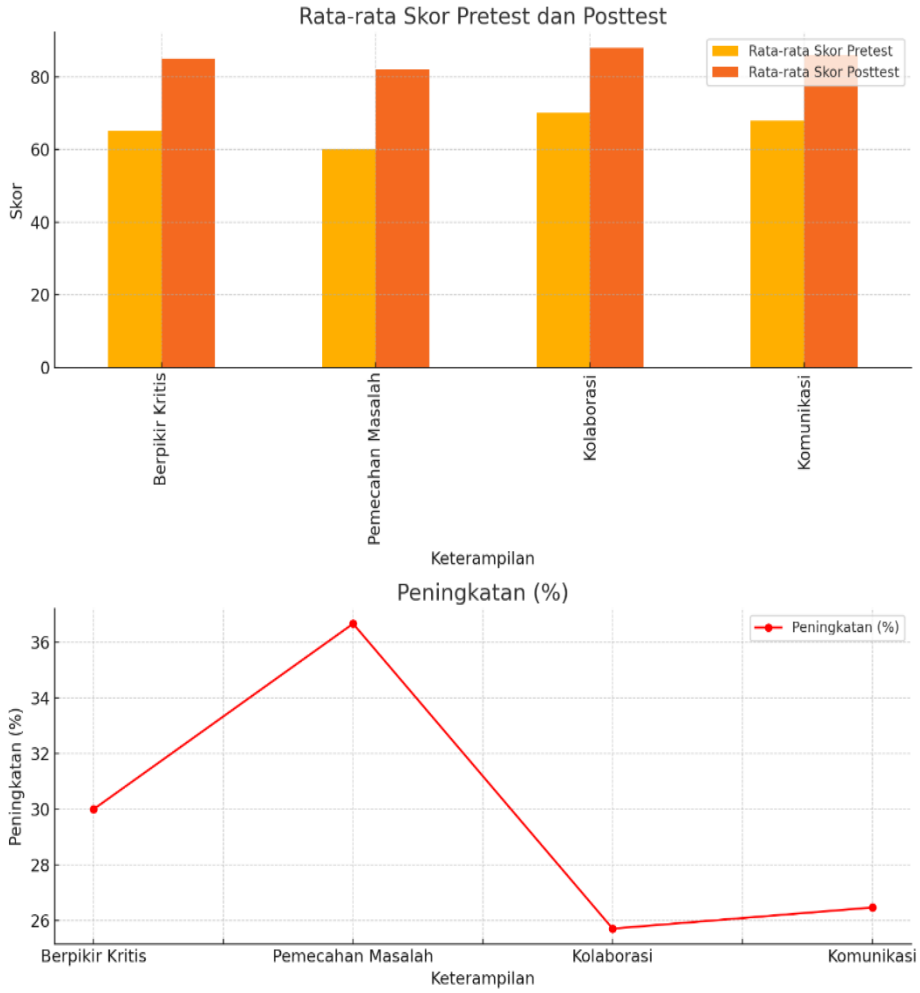
Table 3.2 suggest that the developed materials are not only theoretically sound but also practical and effective for use in educational settings.

Research Objective 3: Effectiveness of Ethno, Inquiry, and Project-Based Physics Teaching Materials

Table 3.3. Details the improvements in multiple skills

Skill	Average Pretest Score	Average Posttest Score	Improvement (%)
Critical Thinking	65	85	30
Problem Solving	60	82	36.67
Collaboration	70	88	25.71
Communication	68	86	26.47

Table 3.3 further illustrates these improvements, visually representing the gains in each skill area. The marked increase across all skills underscores the potential of the Ethno, Inquiry, and Project-based approaches to foster the development of essential competencies in future educato



Research Objective 4: Relationship Between Teaching Materials and Multiple Skills

Table 3.4. Results of the convergent validity analysis

Variable	AVE
Critical Thinking Skills	0.72
Problem-Solving Skills	0.68
Collaboration Skills	0.70
Communication Skills	0.75

Table 3.4. presents the results of the convergent validity analysis, confirming that the variables associated with critical thinking, problem-solving, collaboration, and communication skills are all valid and reliable.

Table.3.5. Result of Discriminant Validity

Variable	Critical Thinking Skills	Problem-Solving Skills	Collaboration Skills	Communication Skills
Critical Thinking Skills	0.85			
Problem-Solving Skills	0.65	0.82		

Variable	Critical Thinking Skills	Problem-Solving Skills	Collaboration Skills	Communication Skills
Collaboration Skills	0.55	0.60	0.84	
Communication Skills	0.62	0.66	0.59	0.87

Table 3.5 shows the discriminant validity results, demonstrating that each skill variable is distinct yet related, supporting the robustness of the constructs.

Table 3.6. Composite Reliability

Variable	Composite Reliability
Critical Thinking Skills	0.90
Problem-Solving Skills	0.88
Collaboration Skills	0.87
Communication Skills	0.91

Table 3.6 shows composite reliability scores, confirming the reliability of the skill variables.

Table 3.7. Path coeficient

Relationship	Path Coefficient	t-Statistic	p-Value	Significance
Critical Thinking -> Problem Solving	0.65	8.45	< 0.01	Significant
Critical Thinking -> Communication	0.58	7.32	< 0.01	Significant
Critical Thinking -> Collaboration	0.60	7.85	< 0.01	Significant
Problem Solving -> Collaboration	0.55	6.74	< 0.01	Significant

Table 3.8. hypothesis testing results

Hypothesis	Path Coefficient	t-Statistic	p-Value	Decision
H1: Critical Thinking -> Problem Solving	0.65	8.20	< 0.01	Accepted
H2: Critical Thinking -> Communication	0.58	7.05	< 0.01	Accepted
H3: Critical Thinking -> Collaboration	0.60	7.40	< 0.01	Accepted
H4: Problem Solving -> Collaboration	0.55	6.50	< 0.01	Accepted

Finally, Table 3.7 and Table 3.8 present the path coefficients and hypothesis testing results, showing significant relationships between critical thinking and other skills, further confirming the effectiveness of the teaching materials.

3.2. Discussion

Research Objective 1: Analysis of Characteristics of Physics Teaching Materials

The Ethno, Inquiry, and Project-based physics teaching materials were designed with the specific objective of enhancing the creative thinking, problem-solving, collaboration, and communication skills of prospective physics teachers. These materials integrate formal science concepts with ethnoscience contexts, allowing students to study physics through the lens of local culture. For instance, the use of "Patok Lele" in the measurement module helps students understand the concept of length and units practically by linking it to traditional measurement methods (Table 3.1). This approach underscores the importance of cultural relevance in facilitating a deeper understanding of scientific concepts (Sumarni, 2023).

In addition to this cultural integration, the materials also incorporate inquiry-based learning, which encourages students to engage in scientific discovery and analysis. Lisa (2023) found that inquiry-based teaching materials can significantly boost student motivation and understanding, thereby strengthening their problem-solving skills. For example, in the linear motion module, students analyze basic movements in pencak silat that follow uniform linear motion patterns, allowing them to connect theory with practical applications in daily life. This inquiry-based approach not only enhances students' analytical abilities but also reinforces critical thinking skills essential for problem-solving (Wahyudi, 2023).

Another key characteristic of these teaching materials is the emphasis on project-based learning, which facilitates direct student involvement in relevant practical tasks. Martawijaya et al. (2023) highlighted that project-based learning can significantly improve students' competence in understanding physics concepts by linking theory with practical application. For instance, the traditional boat-making project, which involves concepts of work and energy, provides a real-world context in which students can observe how physics theories apply to everyday processes. This demonstrates that project-based learning not only enhances practical skills but also fosters students' creative thinking abilities through hands-on experiences (Juliyanto & Trisnowati, 2021).

The Ethno, Inquiry, and Project approaches also emphasize the importance of social interaction and teamwork in the learning process. Maulyda & Erfan (2021) noted that social interaction in science learning can enhance students' understanding of scientific concepts while simultaneously strengthening collaboration and communication skills. In this context, teaching materials that integrate socio-cultural elements and project-based tasks encourage students to work together in solving problems and developing effective communication skills, which are crucial components of 21st-century learning.

Overall, the Ethno, Inquiry, and Project-based physics teaching materials offer a holistic approach to teacher education, focusing on the enhancement of the 4C skills: creative thinking, problem-solving, collaboration, and communication. By integrating cultural context, inquiry-based scientific analysis, and project-based learning experiences, these materials provide prospective teachers with rich, meaningful experiences that not only improve their competencies as educators but also prepare them to address the challenges of modern education. Utilizing pedagogical methods such as Problem-Based Learning and socio-scientific studies, these materials effectively equip prospective teachers with the skills necessary to support interactive, contextual, and relevant learning for their future students.

Research Objective 2: Validity of the Teaching Materials

The validity of the Ethno, Inquiry, and Project-based physics teaching materials in enhancing creative thinking, problem-solving, collaboration, and communication skills among

prospective educators was rigorously evaluated. Based on expert validation, the materials received very high average scores in content validity (4.8), construct validity (4.7), and implementation validity (4.6), all categorized as "Very Good" (Table 3.2). This indicates that the teaching materials are of high quality in terms of content alignment with the curriculum, relevance to local cultural contexts, and their ability to develop essential skills in prospective educators.

These validation results align with previous studies emphasizing the importance of developing Problem-Based Learning (PBL) materials and integrating local wisdom into physics education. Pratama et al. (2021) demonstrated that the PBL model could enhance students' argumentation and critical thinking skills within the context of heat-to-electricity conversion materials. This finding supports the validity of the Ethno, Inquiry, and Project-based teaching materials, which also integrate local elements into physics learning, such as using traditional games or pencak silat to explain physics concepts.

In terms of problem-solving skill development, Mursyida (2024) highlighted the importance of developing PBL-based e-modules that focus not only on technical skills but also on soft skills such as collaboration and communication. The high validity of the Ethno, Inquiry, and Project-based physics teaching materials in terms of construction and implementation suggests that these materials are effective in facilitating the development of such skills, which are essential for prospective educators to meet the challenges of 21st-century education.

Furthermore, Azriyanti (2023) supported these findings in her study on the validation of PBL-based physics e-modules for improving students' critical thinking skills. Her research indicated that well-validated teaching materials have significant potential to enhance students' critical thinking and problem-solving abilities, which are also prioritized in the Ethno, Inquiry, and Project-based teaching materials.

Additionally, Mahmudah et al. (2023) emphasized the importance of integrating local wisdom into physics teaching materials to cultivate students' critical thinking skills. Teaching materials that incorporate ethnoscience are not only culturally relevant but also effective in helping students connect physics concepts with everyday life, thereby enhancing their analytical and critical thinking abilities. The high validity of these ethnoscience-integrated physics teaching materials indicates that this approach can effectively enhance students' understanding of physics concepts and higher-order thinking skills.

Pieter's (2024) research on the integration of ethnoscience into physics teaching materials confirmed that strong validation of teaching materials is crucial to ensuring that they can improve students' science process skills and concept mastery. This demonstrates that the validity of the Ethno, Inquiry, and Project-based physics teaching materials lies not only in their content and construction but also in their effectiveness in enhancing the critical skills required by prospective educators.

Overall, the high validity of the Ethno, Inquiry, and Project-based physics teaching materials indicates that they are not only content- and construct-valid but also highly effective in improving creative thinking, problem-solving, collaboration, and communication skills in prospective educators. This validation provides a strong foundation for the implementation of these materials in physics education, ensuring that prospective educators are well-prepared to develop the skills needed by students in the modern era.

Research Objective 3: Effectiveness of the Teaching Materials

The effectiveness of the Ethno, Inquiry, and Project-based physics teaching materials in enhancing creative thinking, problem-solving, collaboration, and communication skills in prospective teachers is evident from the significant improvement in posttest scores compared to pretest scores. Table 3.7 and 3.8 show that all tested skills improved after using these teaching materials. The average score for critical thinking increased by 30%, problem-solving by 36.67%, collaboration by 25.71%, and communication by 26.47%. The largest increase occurred in problem-solving skills, indicating that this approach is particularly effective in honing students' ability to solve problems critically and analytically.

This effectiveness is consistent with the findings of Martawijaya et al. (2023), who stated that project-based learning combined with the ethno-inquiry approach can significantly enhance students' competence in understanding physics concepts. In this context, the use of teaching aids and physics products generated from these projects helps students apply the theories they have learned to real-life situations, thereby improving their conceptual understanding and higher-order thinking skills. This is reflected in the substantial increase in critical thinking and problem-solving skills.

The inquiry-based approach used in these teaching materials has also proven effective in increasing student motivation and thinking skills. Lisa (2023) found that using inquiry-based teaching materials not only enhances students' knowledge and skills but also motivates them to be more actively engaged in the learning process. This is evident from the improvement in posttest scores across all skills, particularly in critical thinking, where students are encouraged to actively seek answers and solutions through exploration and independent inquiry, as supported by Wahyudi's (2023) findings.

Moreover, the integration of the Ethno-STEM approach in these teaching materials provides a culturally relevant context that not only enhances students' scientific literacy but also connects physics learning with their cultural heritage (Sumarni, 2023). This approach enriches students' learning experiences by linking physics theory with local culture, which has proven effective in enhancing collaboration and communication skills. For example, applying the concept of momentum in karate movements or balance in traditional games like engklek makes it easier for students to understand and communicate complex physics concepts.

Overall, the field trial results indicate that the Ethno, Inquiry, and Project-based physics teaching materials are highly effective in enhancing the targeted skills. The significant improvement in critical thinking, problem-solving, collaboration, and communication skills demonstrates that this approach successfully creates an interactive and relevant learning environment. This is in line with Herliana's (2023) research, which emphasized that inquiry-based teaching modules specifically designed for physics education not only increase student engagement but also align with the independent curriculum requirements, making these teaching materials an effective tool in preparing prospective teachers for the challenges of modern education.

Research Objective 4: Relationship Between Teaching Materials and Multiple Skills

The relationship between the use of Ethno, Inquiry, and Project-based physics teaching materials and the improvement of creative thinking, problem-solving, collaboration, and communication skills in prospective teachers shows a significant correlation, as indicated by the

hypothesis testing and path coefficient results. Based on the data from Table 4.9 and Table 4.12, it can be concluded that there is a strong relationship between critical thinking skills and problem-solving, collaboration, and communication skills, as well as between problem-solving and collaboration skills. This relationship is reinforced by significant path coefficient values, with p-values < 0.01, indicating that these relationships did not occur by chance.

Wahyudi (2023) supports these findings by emphasizing that the inquiry learning model with project tasks can significantly enhance the creativity of prospective physics teachers. This creativity is crucial in developing critical thinking skills, which then contribute to the improvement of problem-solving skills and collaborative abilities, as evidenced by a path coefficient of 0.65 for the relationship between critical thinking and problem-solving. This shows that the higher the critical thinking ability of prospective teachers, the better they are at solving problems creatively and collaboratively.

Furthermore, the project-based learning approach combined with STEAM elements, as described by Indahwati (2023), has proven effective in enhancing students' critical thinking skills. This research is relevant to the finding that critical thinking skills have a significant influence on communication skills, with a path coefficient of 0.58. This indicates that through project-based learning, prospective teachers not only learn to think critically but also develop the ability to communicate their ideas clearly and effectively in complex situations.

The relationship between problem-solving and collaboration is also significant, with a path coefficient of 0.55. This indicates that prospective teachers who are proficient in problem-solving are more likely to excel in working collaboratively with their peers to achieve common goals. Adawiah (2024) highlighted that the Project-Based Learning (PBL) model can enhance student activity and creativity, which are essential for developing collaboration skills. Through PBL, students are taught to work in teams, collectively solve problems, and contribute effectively to group objectives.

The importance of integrating technology into physics learning is also emphasized by Patiño et al. (2023), who showed that technology-based interventions in learning can drive a transformation toward student-centered methods, such as collaboration and inquiry-based learning. This aligns with the findings that the Ethno, Inquiry, and Project approach can improve the communication skills of prospective teachers, which are crucial in the context of modern collaborative learning.

Overall, the analysis results show that the Ethno, Inquiry, and Project-based physics teaching materials are highly effective in enhancing the 4C skills—creative thinking, problem-solving, collaboration, and communication—in prospective teachers. The relationship between these skills is very close, with improvement in one skill positively impacting the others. The high convergent and discriminant validity (Tables 4.6 and 4.7) as well as strong composite reliability (Table 4.8) further support the conclusion that these teaching materials are of high quality and relevant for developing the multiple skills needed by prospective teachers in the modern education era.

5. CONCLUSION

This study demonstrates that Ethno Inquiry and Project-based physics teaching materials significantly enhance the critical thinking, problem-solving, collaboration, and communication

skills of prospective teachers. Expert validation confirmed the materials' high validity, with content, construct, and implementation scores averaging 4.6 to 4.8. Field trials showed substantial improvements in skill levels, with problem-solving increasing by 36.67% and collaboration by 25.71%. These results highlight the effectiveness of integrating ethnoscience, inquiry-based, and project-based approaches in physics education, offering a culturally relevant and interactive learning experience that prepares future educators to meet modern educational challenges.

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REFERENCES

Adawiah, R. (2024). A combination of the project-based learning model and value clarification technique in improving students' critical thinking skills. *Indonesian Journal of Educational Development (IJED)*, 5(1), 68-78. https://doi.org/10.59672/ijed.v5i1.3728

Anggaryani, M. (2024). How to promote the ability of physics teaching materials development through team-based project learning? An action research evidence. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 10(1), 15-26. https://doi.org/10.21009/1.10102

Aswirna, P. (2024). Application of LKPD based on guided inquiry model assisted by PhET simulation to learners' critical thinking skills. *JLTP Unimed*, 2(2), 46. https://doi.org/10.24114/jltp.v2i2.56676

Azriyanti, R. (2023). Validation of the physics e-module based on problem-based learning as independent teaching material to improve critical thinking skills of class XI high school students. *Jurnal Penelitian Pendidikan IPA*, 9(11), 10223-10229. https://doi.org/10.29303/jppipa.v9i11.5809

Creswell, J. W. (2009). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. SAGE Publications.

Gay, L. R., Mills, G. E., & Airasian, P. W. (2012). Educational Research: Competencies for Analysis and Applications. Pearson Education.

Goodson, B., Ge, Q., & Wang, L. (2023). Development and implementation of a two-level inquiry- and project-based modular approach to teaching a second-semester physical chemistry laboratory course. *Journal of Chemical Education*, 100(5), 1885-1894. https://doi.org/10.1021/acs.jchemed.2c01225

Hairida, H., Marmawi, M., & Kartono, K. (2021). An analysis of students' collaboration skills in science learning through inquiry and project-based learning. *Tadris: Jurnal Keguruan dan Ilmu Tarbiyah*, 6(2), 219-228. https://doi.org/10.24042/tadris.v6i2.9320

Harahap, M. (2023). The importance of project-based learning in student entrepreneurship education. *Indo-Mathedu Intellectuals Journal*, 4(2), 471-487. https://doi.org/10.54373/imeij.v4i2.230

Herliana, F. (2023). Development of guided inquiry based on blended learning (GIBBL) teaching module for physics in the independent curriculum. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 9(2), 273-286. https://doi.org/10.21009/1.09210

Hikmah, N. (2023). Impact of the project-based learning model on students' critical and creative thinking skills in science and physics learning: A meta-analysis. *Jurnal Penelitian Pendidikan IPA*, 9(10), 892-902. https://doi.org/10.29303/jppipa.v9i10.4384

Hidayati, T. (2023). The effect of applying problem-based learning model on students' critical thinking ability science subjects in grade V elementary school. *JPI (Jurnal Pendidikan Indonesia)*, 12(3), 576-585. https://doi.org/10.23887/jpiundiksha.v12i3.55235

Hu, S. (2024). Assessing the intention to accept inquiry-based teaching pedagogy among Chinese university students: An extension of technology acceptance model. *Frontiers in Psychology*, 15. https://doi.org/10.3389/fpsyg.2024.1265047

Ilham, M. (2023). Student's critical thinking ability in ethnoscience-based biology learning in the era of digitalization. *Journal of Biology Education*, 12(3), 397-402. https://doi.org/10.15294/jbe.v12i3.74659

Indahwati, S. (2023). Integration of PjBL, STEAM, and learning tool development in improving students' critical thinking skills. *IJORER: International Journal of Recent Educational Research*, 4(6), 808-818. https://doi.org/10.46245/ijorer.v4i6.434

Juliyanto, E., & Trisnowati, E. (2021). Pengembangan bahan ajar mekanika berbasis PBL untuk menyongsong revolusi industri 5.0. *Spektra: Jurnal Kajian Pendidikan Sains*, 7(2), 126. https://doi.org/10.32699/spektra.v7i2.208

Laily, T. (2024). Enhancing scientific argumentation skills through electronic worksheets based on research-oriented collaborative inquiry learning. *KNE Social Sciences*. https://doi.org/10.18502/kss.v9i8.15505

Lisa, T. (2023). Effect size analysis of the use of guided inquiry-based teaching materials on students' competence. *JIPT*, 1(1), 85-95. https://doi.org/10.24036/jipt/vol1-iss1/6

Mahmudah, S., M, A., & Dewantara, D. (2023). Development of physics teaching materials containing local wisdom to train students' critical thinking skills. *Berkala Ilmiah Pendidikan Fisika*, 11(1), 28. https://doi.org/10.20527/bipf.v11i1.14059

Martawijaya, M., Rahmadhanningsih, S., Swandi, A., Hasyim, M., & Sujiono, E. (2023). The effect of applying the ethno-STEM-project-based learning model on students' higher-order thinking skills and misconception of physics topics related to Lake Tempe, Indonesia. *Jurnal Pendidikan IPA Indonesia*, 12(1), 1-13. https://doi.org/10.15294/jpii.v12i1.38703

Maulyda, M., & Erfan, M. (2021). Socio-scientific study: Relationship of students' social interactions with natural sciences learning outcomes. *Spektra: Jurnal Kajian Pendidikan Sains*, 7(2), 103. https://doi.org/10.32699/spektra.v7i2.204

Mursyida, L. (2024). E-modules for computer network practicum based on problem-based learning and peer tutoring: A practical solution to develop 21st-century skills. *Journal of Education Technology*, 8(1), 77-85. https://doi.org/10.23887/jet.v8i1.63568

Nisa, N. (2023). Analyse implementation of inquiry-based learning in physics for learning outcomes and thinking skills. *International Journal of Emerging Research and Review*, 1(3), 000027. https://doi.org/10.56707/ijoerar.v1i3.27

Patiño, A., Ramírez-Montoya, M., & Ibarra-Vazquez, G. (2023). Trends and research outcomes of technology-based interventions for complex thinking development in higher education: A review of scientific publications. *Contemporary Educational Technology*, 15(4), ep447. https://doi.org/10.30935/cedtech/13416

Pieter, J. (2024). Integrating ethnoscience in physics teaching materials and its impact on student's science process skills and mastery concept. *Jurnal Penelitian Pendidikan IPA*, 10(6), 2948-2955. https://doi.org/10.29303/jppipa.v10i6.7210

Prayogi, S. (2024). Inquiry vs. inquiry-creative: Emphasizing critical thinking skills of prospective STEM teachers in the context of STEM learning in Indonesia. *Education Sciences*, 14(6), 593. https://doi.org/10.3390/educsci14060593

Pratama, I., Suyanto, E., & Nyeneng, I. (2021). The effect of problem-based learning models on practicum-based argumentation skills on heat to electricity conversion material. *Spektra: Jurnal Kajian Pendidikan Sains*, 7(1), 82. https://doi.org/10.32699/spektra.v7i1.199

Pratiwi, R. (2024). Effect of science learning on students' critical thinking ability: A review. *International Journal of Scientific and Engineering Studies (IJSES)*, 1(1), 1-5. https://doi.org/10.56566/ijses.v1i1.105

Sumarni, W. (2023). Blended inquiry learning with ethno-STEM approach for first-semester students' chemical literacy. *Jurnal Pendidikan IPA Indonesia*, 12(3), 439-450. https://doi.org/10.15294/jpii.v12i3.45879

Sudarmin, S., Pujiastuti, R., Asyhar, R., Prasetya, A., Diliarosta, S., & Ariyatun, A. (2023). Chemistry project-based learning for secondary metabolite course with ethno-STEM approach to improve students' conservation and entrepreneurial character in the 21st century. *Journal of Technology and Science Education*, 13(1), 393. https://doi.org/10.392