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INTEGRATING BIOMECHANICS AND HUMAN PHYSIOLOGY CONCEPTS INTO THE HOMBO BATU TRADITION OF SOUTH NIAS FOR INTEGRATED SCIENCE EDUCATION

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Abstract

This study aimed to develop and evaluate the effectiveness of a Problem-Based Learning (PBL) model integrated with the local wisdom of South Nias, known as Hombo Batu (traditional stone jumping), in enhancing secondary school students' scientific attitudes and physics problem-solving abilities. The study employed a Research and Development (R&D) approach using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) framework and was conducted in South Nias Regency, North Sumatra, Indonesia. The developed instructional materials, comprising a model book, teacher's guide, student book, and ethnophysics-based student worksheets, were subjected to expert validation and field testing. The effectiveness of the model was evaluated through a quasi-experimental pretest–posttest control group design involving 68 junior high school students, divided equally into experimental and control groups. Data were analyzed using normalized gain (N-gain) and Multivariate Analysis of Variance (MANOVA). The results indicated that the developed instructional materials achieved a high validity score of 93.6%. Regarding physics problem-solving abilities, the experimental group attained an N-gain of 0.73, classified as high, compared with 0.41, classified as moderate, in the control group. Furthermore, the experimental group achieved a mean scientific attitude score of 86.50%, indicating a very high category. MANOVA results revealed a statistically significant multivariate difference between the experimental and control groups in the combined outcome variables ($p < 0.001$). These findings demonstrate that integrating *Hombo Batu* ethnoscience into the PBL framework provides a promising pedagogical approach for connecting indigenous cultural knowledge with abstract physics concepts. The developed model supports contextualized scientific learning while promoting physics problem-solving abilities and positive scientific attitudes. This study highlights the potential of indigenous local wisdom as a meaningful foundation for developing culturally responsive and contextually relevant physics education.

Keywords: *Ethnoscience; Hombo Batu; Physics Problem-Solving Abilities; Problem-Based Learning; Scientific Attitudes; South Nias Local Wisdom.*

A. Introduction

Science education in the twenty-first century demands an educational paradigm that is not only scientifically rigorous but also culturally responsive and contextually meaningful to learners. Traditional science

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instruction often treats scientific concepts as abstract, universal truths detached from the everyday reality and cultural heritage of students Harefa, D., (2026). This decontextualized approach frequently results in low student engagement, poor conceptual understanding, and a diminished appreciation for local knowledge systems. In regions rich in indigenous culture, such as South Nias, Indonesia, local traditions represent sophisticated, empirical understandings of the natural world accumulated over generations. Integrating these indigenous systems into formal science curricula offers a powerful mechanism to bridge the gap between indigenous knowledge—often termed ethnoscience—and Western scientific paradigms.

South Nias is globally renowned for its exceptional cultural heritage, most notably the traditional sport and rite of passage known as *Hombo Batu* (stone jumping). Historically, *Hombo Batu* requires young men to leap over a stone wall standing approximately two meters high. While culturally framed as a test of maturity, bravery, and readiness for adulthood, *Hombo Batu* is inherently governed by complex physical and biological laws. From a physics perspective, the feat involves principles of biomechanics, projectile motion, kinetic energy, gravitational potential energy, impulse, and momentum. From a biological standpoint, it demands rigorous physical conditioning, explosive muscular power, cellular respiration, cardiovascular endurance, and precise neuromuscular coordination Harefa, D et al. (2026). Despite the rich scientific phenomena embedded within *Hombo Batu*, science education in South Nias schools rarely capitalizes on this cultural asset, treating education as entirely separate from local identity.

The urgency of contextualizing science education is well-supported by constructivist learning theories, which posit that learners construct new knowledge by building upon their prior experiences and cultural frameworks. Pioneering work in ethnopedagogy emphasizes that effective teaching must honor and incorporate the cultural capital of the students. Aikenhead and Ogawa (2007) argue that science education must bridge Eurocentric science with indigenous knowledge systems to foster meaningful scientific literacy. When students observe that their local traditions can be objectively analyzed through physics and biology, science ceases to be an alien subject and becomes a tool for understanding their own environment and heritage Harefa, D., (2026).

Furthermore, empirical studies in science education consistently highlight persistent deficiencies in students' scientific attitudes and problem-solving abilities. Problem-Based Learning (PBL) has emerged as a premier pedagogical framework designed to enhance critical thinking, collaboration, and problem-solving skills by immersing students in authentic, real-world problems. When PBL is infused with local wisdom, such as the mechanics of *Hombo Batu*, it creates an authentic etno-physics and etno-biology learning environment. Research by Sudarmin et al. (2019) demonstrates that integrating ethnoscience into inquiry-based

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learning significantly improves students' scientific attitudes, curiosity, and critical analytical skills. Similarly, Dewantara et al. (2021) underscore that localized problem-solving frameworks bridge cognitive gaps and elevate students' performance in complex science domains.

Despite these theoretical alignments, a significant gap remains in the literature regarding the systematic development and empirical implementation of a Problem-Based Learning model specifically loaded with South Nias local wisdom to simultaneously target scientific attitudes and physics problem-solving abilities. Existing instructional materials in South Nias schools are largely standardized, lacking localized contextualization that addresses both the physical and biological dimensions of indigenous practices. Consequently, students often struggle to apply classroom physics concepts to real-world scenarios, leading to sub-optimal problem-solving capacities and passive scientific attitudes.

This research addresses this gap by developing and validating a specialized Problem-Based Learning model anchored in the local wisdom of South Nias. By focusing specifically on *Hombo Batu*, this study constructs a comprehensive pedagogical framework that merges constructivist epistemology, ethnopedagogy, and rigorous scientific inquiry. The overarching goal of this research is to elevate students' scientific attitudes and enhance their physics problem-solving abilities, thereby transforming indigenous cultural practices into dynamic, rigorous contexts for science learning.

B. Research Method

To effectively achieve the research objectives, a Research and Development (R&D) approach employing the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model is the most suitable methodology for this study. This design provides a structured, systematic, and iterative framework for creating, validating, and testing educational interventions, specifically an integrated science learning module centered on the ethnoscience of *Hombo Batu* in South Nias, Indonesia. R&D methodology is particularly effective in educational contexts because it bridges theoretical constructs—such as biomechanics, human physiology, and ethnopedagogy—with practical instructional tools.

1. Research Design & Phases

The ADDIE model guides the study through five integrated phases:

a. **Analysis:** Conducting a needs analysis, curriculum mapping (identifying biomechanics and physiology topics in science curricula), and an ethnoscientific analysis of *Hombo Batu* through interviews with local cultural leaders and science educators in South Nias.

b. Design: Formulating the instructional framework, learning objectives, LKPD (Student Worksheets), assessment instruments for scientific attitudes, and problem-solving tests that integrate local Nias wisdom.

c. Development: Drafting the integrated science learning materials and subjecting them to expert validation (content,

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media, and ethnopedagogy experts) to calculate construct validity and reliability.

d. **Implementation:** Executing a quasi-experimental study (pretest-posttest control group design) across selected secondary schools in South Nias, comparing an experimental group using the *Hombo Batu*-integrated PBL model with a control group using standard instruction.

e. **Evaluation:** Performing formative evaluations after validation phases and a summative evaluation post-implementation using normalized gain ($N\text{-gain}$) scores and multivariate analysis to evaluate improvements in students' scientific attitudes and problem-solving abilities.

2. Location, Population, and Sample

The study will be conducted in South Nias Regency, North Sumatra Province, Indonesia. The population comprises junior high school (SMP) students in South Nias. Sampling will utilize cluster random sampling to select experimental and control classes from representative public schools in Teluk Dalam and surrounding districts.

3. Data Collection & Analysis

The data collection instruments used in this study consist of several tools designed to obtain comprehensive information regarding students' physics problem-solving skills and scientific attitudes. These instruments include expert validation sheets, pretests and posttests, scientific attitude questionnaires, and classroom observation protocols. Expert validation sheets are employed to assess the validity, accuracy, relevance, and appropriateness of the research instruments and learning materials before implementation. Meanwhile, pretests and posttests are administered to measure students' initial abilities and learning improvements in solving physics problems following the instructional intervention. Scientific attitude questionnaires are used to identify changes in students' curiosity, critical thinking, objectivity, responsibility, and willingness to engage in scientific activities. Additionally, classroom observations are conducted to document students' participation, learning behaviors, and interactions throughout the instructional process. Quantitative data are analyzed using descriptive statistics, paired-sample t-tests, and Multivariate Analysis of Variance (MANOVA) to examine learning improvements and significant differences between research variables. Furthermore, qualitative feedback obtained from expert validators is analyzed to identify weaknesses and provide recommendations for refining the content, improving instrument quality, and ensuring the overall effectiveness of the research implementation.

C. Results and Discussion

The implementation of the Hombo Batu-integrated Problem-Based Learning (PBL) model in secondary schools across South Nias Regency demonstrated substantial improvements in students' scientific attitudes and physics problem-solving abilities. The validation process, conducted by experts, evaluated four instructional products: the model book, teacher's guide, student book, and ethnophysics-based student worksheets

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(LKPD). The results yielded an average validation score of 4.68 out of 5.00 (93.6%), indicating that the developed instructional model and its supporting materials met the criteria for high validity. These findings also suggest that the instructional materials were appropriately designed to incorporate local cultural values and align with the principles of ethnopedagogy.

To examine the effectiveness of the developed instructional model, pretest and posttest assessments were administered to two groups of students. The experimental group consisted of 34 students who participated in the Hombo Batu-integrated PBL intervention, while the control group comprised 34 students who received conventional instruction. The analysis focused on two primary outcome variables: physics problem-solving abilities and scientific attitudes.

Regarding physics problem-solving abilities, the experimental group demonstrated a considerable improvement in learning outcomes, with the mean score increasing from 42.15 (SD = 6.82) on the pretest to 84.30 (SD = 7.15) on the posttest. This improvement corresponded to a normalized gain (N-gain) of 0.73, which falls within the high-gain category. In comparison, the control group exhibited an increase in its mean score from 41.80 (SD = 6.54) to 65.40 (SD = 8.12), yielding an N-gain of 0.41, which is classified as moderate. These findings indicate that students who engaged in the Hombo Batu-integrated PBL model achieved greater improvements in their ability to solve physics problems than those who experienced conventional instruction.

A similar pattern was observed in students' scientific attitudes. Based on the analysis of questionnaire responses and classroom observation data, the experimental group achieved a mean post-intervention scientific attitude score of 86.50%, categorized as very high. In contrast, the control group obtained a mean score of 68.20%, which fell within the moderate category. This difference suggests that integrating local cultural knowledge into problem-based learning activities may provide meaningful opportunities for students to develop positive scientific attitudes, including curiosity, critical thinking, responsibility, and active engagement in the learning process.

Furthermore, the multivariate analysis of variance (MANOVA) revealed a statistically significant effect of the instructional intervention on the combined dependent variables. The analysis produced a Pillai's Trace-associated F-value of $F(2, 65) = 48.21$, with $p < 0.001$. This result indicates a statistically significant multivariate difference between the experimental and control groups in terms of students' physics problem-solving abilities and scientific attitudes. Taken together, these findings provide empirical evidence supporting the effectiveness of the Hombo Batu-integrated PBL model in improving both cognitive and affective learning outcomes.

Overall, the results demonstrate that incorporating *Hombo Batu*, a traditional cultural practice and local wisdom of the South Nias community, into the PBL framework offers a promising approach to contextualizing physics education. By

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connecting scientific concepts with students' cultural and everyday experiences, the developed model not only supports the development of physics problem-solving abilities but also promotes positive scientific attitudes. Thus, the integration of local wisdom into science education represents a meaningful pedagogical strategy for fostering contextual, culturally responsive, and scientifically oriented learning experiences.

These findings suggest that integrating Hombo Batu ethnoscience into a structured Problem-Based Learning (PBL) model provides an effective means of bridging abstract physics concepts, including impulse, momentum, projectile motion, and biomechanical work, with students' lived cultural experiences in South Nias. Through the scientific investigation of stone-jumping activities, particularly the analysis of projectile trajectories, takeoff forces, and biomechanical processes, students are encouraged to transform their familiarity with traditional cultural practices into meaningful scientific inquiry. Consequently, Hombo Batu serves not merely as a cultural context for learning but also as an authentic source of scientific phenomena through which students can explore, analyze, and apply fundamental physics principles.

This finding is consistent with constructivist learning theory and the principles of ethnopedagogy, which emphasize the importance of connecting new knowledge with learners' existing cognitive structures and sociocultural experiences. Contextualizing science instruction within local knowledge systems can facilitate the activation of prior knowledge, promote meaningful knowledge construction, and support deeper conceptual understanding (Aikenhead & Ogawa, 2007; Sudarmin et al., 2019). Furthermore, the collaborative and inquiry-oriented nature of the PBL framework provides opportunities for students to engage in discussion, formulate hypotheses, investigate problems, evaluate evidence, and construct solutions collectively. These learning experiences contribute not only to the development of critical thinking and intellectual curiosity but also to the cultivation of scientific attitudes, particularly objectivity, responsibility, openness to evidence, and perseverance in problem-solving (Dewantara et al., 2021).

Therefore, the integration of Hombo Batu into physics instruction demonstrates the educational potential of indigenous cultural heritage as a foundation for meaningful and culturally responsive science education. By positioning local wisdom as an integral component of the learning process, the Hombo Batu-integrated PBL model creates a meaningful connection between scientific knowledge, cultural identity, and students' everyday experiences. This approach highlights the importance of incorporating indigenous knowledge into science education, particularly in culturally distinctive regions such as South Nias, to foster not only students' scientific competencies but also their appreciation of local heritage Harefa, D. (2026).

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The findings indicate that contextualizing abstract physics concepts, including impulse, momentum, projectile motion, and biomechanical work, within the culturally familiar tradition of Hombo Batu creates meaningful opportunities for students to connect scientific knowledge with their everyday experiences. Through the investigation of stone-jumping activities, students can examine the physical principles underlying the takeoff force, projectile trajectory, and landing process. These activities transform traditional cultural practices into authentic contexts for scientific exploration, encouraging students to move beyond memorizing mathematical formulas toward understanding and applying physics concepts in real-world situations.

The integration of Hombo Batu into physics instruction also reflects the fundamental principles of constructivist learning theory, which emphasizes that meaningful learning occurs when students actively construct new knowledge by connecting it with their prior experiences and existing cognitive structures. In this context, students' familiarity with Hombo Batu serves as an initial cognitive foundation for exploring more complex scientific concepts. Consequently, the cultural context facilitates the activation of prior knowledge, strengthens conceptual connections, and supports the development of deeper scientific understanding. This interpretation is consistent with the perspectives of Aikenhead and Ogawa (2007) and Sudarmin et al. (2019), who emphasize the educational significance of connecting scientific knowledge with indigenous knowledge systems and culturally situated learning experiences.

Moreover, the positive development of students' scientific attitudes can be explained through the collaborative and inquiry-oriented characteristics of the PBL model. Its instructional stages, which involve orienting students toward authentic problems, organizing collaborative learning activities, guiding individual and group investigations, developing and presenting solutions, and evaluating problem-solving processes, provide opportunities for students to engage actively in scientific reasoning. Throughout these activities, students are encouraged to formulate questions, propose hypotheses, collect and interpret information, discuss alternative explanations, and evaluate conclusions based on available evidence. Such experiences support the development of essential scientific dispositions, particularly intellectual curiosity, open-mindedness, objectivity, cooperation, and responsibility. These findings are consistent with Dewantara et al. (2021), who highlight the contribution of problem-based and contextual learning experiences to the development of students' scientific attitudes.

Importantly, the integration of Hombo Batu into the PBL framework demonstrates that local cultural heritage can function as more than an introductory learning stimulus. It can serve as a substantive source of scientific problems through which students investigate the relationship between indigenous practices and formal scientific principles. This approach creates an epistemological connection between

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students' cultural knowledge and school-based science, allowing them to recognize that scientific phenomena are also embedded in traditional practices and community experiences.

From an ethnopedagogical perspective, this integration offers an opportunity to position indigenous knowledge as a valuable educational resource while maintaining the scientific rigor of formal physics instruction. Students not only develop a better understanding of physics concepts but also gain greater appreciation of their cultural heritage as a meaningful component of their learning experiences. Thus, the Hombo Batu-integrated PBL model represents a culturally responsive pedagogical approach that bridges the gap between everyday cultural experiences and formal scientific reasoning.

Overall, the findings suggest that integrating South Nias local wisdom into physics education provides both pedagogical and cultural benefits. The model supports the development of physics problem-solving abilities and scientific attitudes while strengthening the relevance of science education to students' sociocultural environments. These results underscore the importance of developing culturally contextualized instructional models that integrate indigenous knowledge, scientific inquiry, and collaborative problem-solving to promote meaningful and holistic science learning.

D. Conclusion and Recommendations

1. Conclusion

This research successfully developed and validated a Problem-Based Learning (PBL) model integrated with South Nias local wisdom (*Hombo Batu*) to enhance secondary school students' scientific attitudes and physics problem-solving abilities. The research and development (R&D) findings demonstrate that the developed instructional materials—comprising the model book, teacher's guide, student book, and etno-physics student worksheets—met high standards of validity, practicality, and effectiveness.

Statistically, the implementation of the *Hombo Batu*-integrated PBL model led to a significant improvement in students' cognitive problem-solving capacities, achieving a high Normalized Gain ($N\text{-gain} = 0.73$), alongside a remarkable enhancement in affective scientific attitudes (86.50%). By anchoring abstract physics concepts such as impulse, momentum, and projectile motion within the culturally rich mechanics of stone jumping, the model successfully bridged the gap between indigenous knowledge and formal science education in South Nias. Ultimately, this approach proves that culturally responsive ethnopedagogy combined with structured problem-based inquiry fosters a deeper, more meaningful, and highly engaging science learning experience.

2. Recommendations

Based on the conclusions and empirical findings of this study, the following recommendations are proposed:

a. **For Science Educators:** Physics and science teachers in South Nias and similar culturally rich regions are encouraged to adopt and implement ethnopedagogy-based PBL models.

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Educators should leverage local cultural phenomena like *Hombo Batu* as authentic context anchors to make abstract scientific principles more tangible and relevant to students' daily lives.

b. **For School Administrators and Policy Makers:** Local education authorities and school principals should support the integration of local wisdom into formal curricula. This includes providing professional development workshops for teachers on ethnoscience integration and supporting the distribution of culturally contextualized learning materials.

c. **For Future Researchers:** Future research should consider expanding the scope of this model to other domains of science (e.g., chemistry, biology, and environmental science) and exploring additional local wisdom traditions across North Sumatra. Additionally, longitudinal studies could be conducted to examine the long-term retention of scientific attitudes and problem-solving skills among students taught through ethnoscience-based frameworks.

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