Development of Ethnoscience-Based Physics Teaching Materials to Improve Students' Argumentation Skills

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Abstract *- This study aims to develop ethnoscience-based physics teaching materials by integrating local cultural wisdom to enhance high school students' argumentation skills. The development model employed is the 4D model: Define, Design, Develop, and Disseminate. The teaching materials were designed based on students' needs and characteristics. Validation results from two experts in content and media indicate that the materials are feasible for use, with feasibility scores of 75% and 83.3%, respectively. Revisions were suggested in terms of ethnoscience examples and layout design. The practicality test showed highly positive responses from teachers (85%) and positive responses from students (84.8%), indicating that the materials are easy to use and support meaningful learning. In terms of effectiveness, the average gain score was 21.797, with a symmetrical data distribution (skewness = -0.418) and normality (p = 0.163 based on the Shapiro-Wilk test). The Paired Samples t-Test showed a significant result (t = -11.669; p < 0.001), indicating a significant difference between the pre-test and post-test scores. The average N-Gain score of 0.777 is categorized as high, suggesting that the developed teaching materials effectively support students in constructing logical, structured, and evidence-based arguments.*

Keywords: *Teaching Material; Ethnoscience; Students' Argumentation Skills*

INTRODUCTION

Twenty first-century education emphasizes the importance of developing higher-order thinking skills, one of which is scientific argumentation. This skill plays a critical role in science learning, particularly in physics, as it enables students to express opinions, analyze data, construct logical arguments, and defend ideas based on relevant evidence (Mubarok & Danawan, 2020). In the context of physics education, scientific argumentation serves as a means to foster scientific reasoning and evidence-based decision-making.

However, field observations reveal that students' argumentation skills remain relatively low. According to the results of PISA 2022 released in December 2023, Indonesia ranked near the bottom in science literacy, placing around 76th out of 81 participating countries. The average science literacy score of Indonesian students was 383, significantly below the OECD average of 485. Only about 34% of Indonesian students reached level 2 or above, compared to the OECD average of 76%. This indicates that the majority of Indonesian students still struggle to demonstrate basic scientific thinking skills, including evidence-based argumentation. Although there was a slight improvement in Indonesia's percentile-based ranking compared to the 2018 PISA results with a rise of approximately six positions in the science literacy category (OECD, 2023) overall, Indonesian students' abilities in critical thinking and scientific argumentation remain low, necessitating focused efforts to improve the quality of education. Furthermore, the rapid development of technology and information presents additional challenges, including a decline in students' awareness of local culture and national identity.

Students' argumentation skills must be developed systematically. Toulmin (2003) proposed that scientific arguments consist of several key components: claim, data/grounds, warrant, backing, qualifier, and rebuttal. Through this structure, students are trained not only to make assertions but also to build and defend arguments based on strong scientific reasoning (Kurniasari & Setyarsih, 2017); (Irvan Baharsyah & Admoko, 2020).

One innovative approach to address these challenges is the integration of ethnoscience into physics education. Ethnoscience, derived from *ethnos* (people/ethnic group) and *scientia* (knowledge), refers to local scientific knowledge passed down through generations within a community's culture (Puspasari et al., 2020). This approach aligns with the objectives of the Merdeka Curriculum and serves as a strategic alternative for instilling cultural values and enhancing students' understanding of their local potential.

Lombok, particularly its coastal areas, is rich in cultural traditions that embody scientific concepts. One notable tradition that reflects the integration of culture and natural phenomena is *Bau Nyale*, an annual ritual of the Sasak people rooted in the legend of Princess Mandalika. This tradition follows natural cycles, namely the appearance of *nyale* (sea worms), which is influenced by tides and lunar phases (Saharudin, 2016). Beyond cultural preservation, this tradition also illustrates physics concepts such as waves, fluid pressure, temperature, and periodic time. Other cultural practices such as *menciro'* in Tanjung Luar Village, *tenun sesek* (traditional weaving), *Gendang Beleq* (traditional drumming), and local cuisine like *poteng reket*, also hold great potential as ethnoscientific contexts for physics learning (Hikmawati et al., 2020); (Murdi et al., 2023).

The application of ethnoscience in learning has been proven to increase students' motivation, understanding, and argumentation skills. Research by Novanda et al. (2024) demonstrated that using ethnoscience-based student worksheets (LKPD) significantly improved students' scientific argumentation abilities and was

deemed feasible for classroom implementation. Ethnoscience provides a more contextual learning experience that is closely related to students' daily lives, making physics learning less abstract.

Although previous studies have demonstrated the effectiveness of ethnoscience-based student worksheets (LKPD) in enhancing scientific argumentation skills (Novanda et al., 2024), research focusing on the development of comprehensive ethnoscience-based teaching materials aimed at improving scientific argumentation skills at the high school level remains very limited. This highlights the need for the development of more complete and systematic teaching materials, not only in the form of worksheets but also including modules, teacher guides, and contextualized learning activities.

Therefore, there is a need for innovative physics learning materials that integrate ethnoscience, allowing students to understand physics concepts through familiar cultural contexts. The development of such materials is expected to enhance higher order thinking skills, particularly analytical thinking and scientific argumentation. Furthermore, this approach can make physics learning more contextual, relevant, and meaningfu.

Based on the aforementioned discussion, this study aims to develop ethnoscience-based physics teaching materials to improve students' argumentation skills. Although various studies have highlighted the importance of ethnoscience, most have been limited to conceptual studies or general integration into learning. Few studies have specifically developed physics teaching materials based on local ethnoscience (Bau Nyale) that are systematically designed to enhance high school students' argumentation skills. Through this approach, students are expected to understand physics concepts within the framework of their local cultural heritage, making learning more meaningful and relevant to their lives. Additionally, the study aims to analyze the effectiveness of the developed materials in enhancing students' understanding of the relationship between science and cultural practices in Lombok. Thus, the results of this study are expected to offer an alternative physics learning model that is more contextual and oriented toward the development of higher order thinking skills.

RESEARCH METHODS

This study employed a research and development (R&D) method aimed at producing valid, practical, and effective ethnoscience-based physics teaching materials to improve students' argumentation skills. The development model used was the 4D model—Define, Design, Develop, and Disseminate—proposed by Thiagarajan et al. (1974).

The define stage involved a needs analysis through curriculum review, analysis of student characteristics and concepts, interviews with physics teachers, and literature studies. This stage aimed to identify learning problems and the need for teaching materials that integrate local culture in Lombok.

The design stage focused on drafting the initial version of the teaching materials, including the development of an argumentation skills test instrument based on the Toulmin Argumentation Pattern indicators, selection of appropriate media, organization of instructional content, and integration of cultural elements. The materials developed were then evaluated in the Develop stage through expert validation and field testing. Validation was carried out by content and media experts, assessing aspects such as content, language, presentation, and visuals. After revisions based on the validation results, the materials were tested in a small group (5–10 students) and subsequently in a larger group (10–30 students). Students' argumentation skills were analyzed using pre-tests and post-tests designed to assess their ability to construct logical scientific arguments, support them with relevant evidence, and relate them to physics concepts contextualized within local culture.

The instruments used in this study included expert validation sheets, an argumentation thinking test, and teacher and student response questionnaires. The initial validity of the teaching materials was assessed using a Likert scale (1–4) and analyzed descriptively to determine the percentage of validity. The validity criteria are presented in the following table.

Table 1. alidity criteria for teaching materials

Persentage (%)	Description
85-100 %	Very valid
70-84 %	Valid
50-69 %	Fairy valid
≤ 50%	Not valid

The formula used to calculate the validity score is as follows:

$$P \frac{\Sum x}{\Sum xi} \times 100\% \qquad (1)$$

Explanation:
P = validity percentage
$\sum x$ = total obtained score
Σxi = ideal maxsimum score

Secondly, the teaching material was tested through a trial phase. The trial was conducted using questionnaires distributed to teachers and students regarding the usefulness, clarity, and engagement of the materials. The responses were analyzed descriptively and converted into percentage scores, which were interpreted as follows:

Table 2. practicality criteria

Percentage (%)	Category
85-100 %	Very practical
70-84 %	Practical
50-69 %	Fairly practical
≤ 50%	Not practical

To ssess the effectiveness of the teaching materials in measuring students' argumentation skills, a score improvement analysis was conducted using the N-Gain test. This test aims to determine the extent to which students' ability to present scientific arguments improves after using the developed teaching materials. The N-Gain value is calculated using the following formula:

$$N - gain = \frac{Spost - Spre}{Spmax - Spre} \quad (2)$$

Description:
Spos = posttest score
Spre = Pretest score
Smax = maximum possible score

The N-Gain calculation results are then interpreted using the classification proposed by Meltzer, as shown in Tabel 3.

Table 3. N- Gain classification

N- gain value	Interpretation
g >0,7	High
0,3 <g ≤0,7	Medium
g ≤0,3	Low

This study was conducted in May 2025 at MAN 3 Lombok Tengah, involving students as test subjects to evaluate the developed teaching material.

RESULTS AND DISCUSSION

Results

This study produced ethnoscience-based physics teaching materials designed to enhance high school students' argumentation skills. The development process followed the four stages of the 4D model: Define, Design, Develop, and Disseminate.

The define stage, interviews and literature reviews were conducted to identify students' learning difficulties and the need for contextual teaching materials. The findings revealed that students struggled to understand abstract physics concepts and lacked instructional materials that incorporated local cultural contexts. The Design stage involved the development of content based on Lombok's cultural traditions, including topics such as thermal phenomena, light refraction and reflection, hydrostatic pressure, and ocean dynamics. The teaching materials were developed in the form of printed modules tailored to students' needs and school conditions.

The ethnoscience-based teaching material consists of three main sections: the introduction, the core content, and the closing section.

1. *The introduction*

Introduction section includes the cover page, preface, instructions for using the module, table of contents, list of tables, concept map or topic overview, and learning objectives.

Figure 1. Cover Page of the Teaching Material

Figure 1 is an example of the cover of the developed teaching material.

2. *Content/ Material Section*

The ore section serves as the main component of the teaching material, presenting contextual content based on the Bau Nyale culture. This section includes an introductory paragraph for each chapter/topic, presentation of the material, learning activities, and example problems. The following is an example of the content layout of the teaching material.

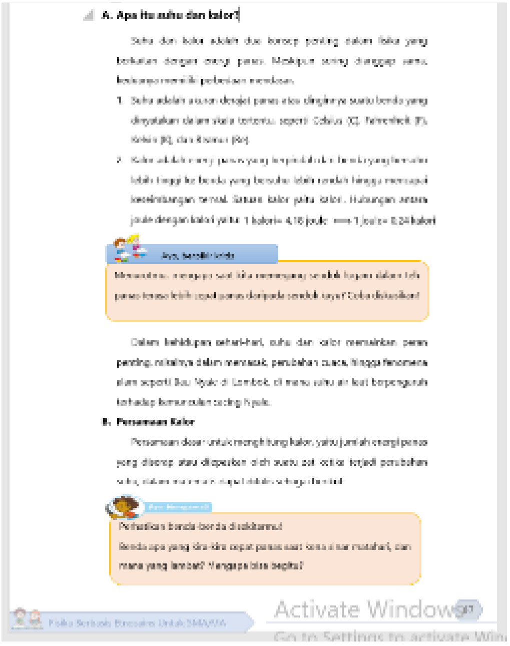

Figure 2. Content Display of the Teaching Material

3. *Closing Section*

The losing section consists of a summary of the material, end-of-chapter evaluation/exercise questions, and a bibliography. The following is an example of the layout of the closing section of the teaching material.

At the Develop stage, expert validation was conducted to assess the content, language, presentation, and integration of ethnoscience.

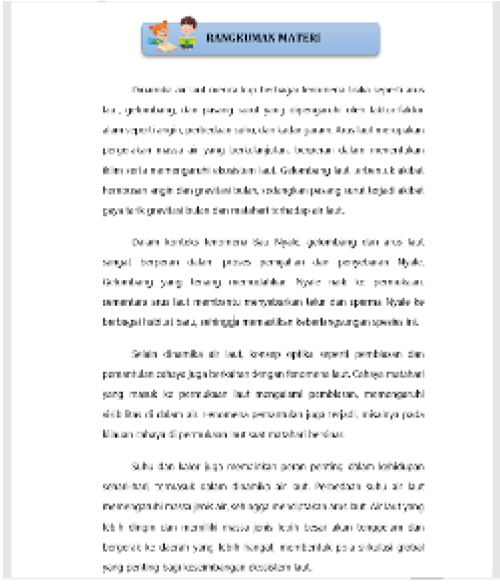

Figure 3. Closing Section of the Teaching Material

Two physics education experts served as validators, evaluating the material using a Likert scale-based evaluation sheet. The validation results indicated that the teaching material met both pedagogical and content standards. The quantitative validation results are summarized as follows.

Table 3. Expert Validation Scores for Teaching Material Feasibility

Validator	Score (%)	Qualification	Criteria
Validator 1	75.0%	Valid	Minor revision
Validator 2	83.3%	Valid	Minor revision

These results indicate a high level of validity, suggesting that the teaching material is feasible for limited trial implementation after minor revisions.

Table 4. Pre-Test and Post-Test data on Argumenttation Skills

Average Pre-test score	Average Post-test Score	N-gain score
71,171875	92.96875	0.77743055

Based on Table 4, the average pre-test score of 71.17 reflects students' initial abilities prior to the intervention, while the average post-test score of 92.968 demonstrates a substantial improvement in understanding after utilizing the developed material. The N-gain score of 0.777 is categorized as high, according to Hake's (1998) criteria. This indicates that the ethnoscience-based teaching material is highly effective in enhancing students' argumentation skills. The observed improvement suggests that integrating physics concepts with local cultural contexts (ethnoscience) facilitates students' ability to organize information, evaluate evidence, and construct logical arguments supported by real-world contexts. Consequently, the teaching material not only improves cognitive skills but also reinforces the cultural relevance in developing meaningful scientific arguments.

Table 5. Results of Teacher and Student Response Questionnaire Assessment

Respondent	Score (%)	Criteria	Notes
Physics subject teachers	85 %	Very good	The eaching material is excellent because it includes a mind map/concept map, which greatly supports and helps students in recalling and understanding the main points of the lesson
11th-grade science students	84,8 %	good	-

The practicality assessment also yielded positive results. Students provided an average score of 87.7%, which falls into the "very high" category. Classroom observation data indicated positive engagement across three key indicators: students' participation in discussions and their ability to construct scientific arguments were categorized as "good," while their ability to connect physics concepts with local cultural phenomena was rated as "very good".

Discussion

The result of this study demonstrate that the development of ethnoscience-based physics teaching materials can significantly contribute to the enhancement of students' scientific argumentation skills. The development process followed the 4D model (Define, Design, Develop, and Disseminate), although this study was limited to the Develop stage, aiming to produce teaching materials that were validated in terms of validity, practicality, and effectiveness prior to broader implementation.

In the Define stage, interviews and literature reviews revealed that students experienced difficulties in understanding abstract physics concepts. One contributing factor was the lack of teaching materials that relate physics learning to familiar local cultural contexts. This finding aligns with the fundamental principles of ethnoscience, which emphasize the importance of cultural integration in science education to make learning more contextual and meaningful.

In the Design stage, the teaching content was developed based on local cultural phenomena in Lombok, such as *Bau Nyale*, ocean waves, and natural optical phenomena. The selected topics—thermal phenomena, light refraction and reflection, hydrostatic pressure, and ocean dynamics—strengthen the connection between physics concepts and students' daily experiences. The teaching material was developed in the form of a printed module, considering the school's infrastructure and the characteristics of the students, to ensure optimal accessibility.

The Develop stage involved validation by two physics education experts, who evaluated the content, language, presentation, and ethnoscience integration. The validation results showed scores of 75% and 83.3%, both categorized as valid with minor revisions required. The high level of validity indicates that the module meets pedagogical and content standards and is suitable for limited trial implementation after slight improvements.

The effectiveness of the teaching material was also tested through measurements of students' argumentation skills before and after the learning process. The average pre-test score of 71.17 increased to 92.97 in the post-test. This improvement resulted in an N-gain score of 0.777, which, according to Hake's (1998) criteria, is considered high. These findings suggest that the integration of ethnoscience within the teaching material effectively supports significant improvement in students' ability to organize information, evaluate evidence, and construct logical scientific arguments. The ethnoscience approach enhances scientific argumentation because local cultural phenomena, such as Bau Nyale, allow students to observe real-life events, making the claims and data they use more relevant and easily connected to the physics concepts being studied, such as waves, fluid pressure, and light refraction. This confirms the notion that culturally contextualized learning can deepen conceptual understanding while enhancing higher order thinking skills.

These results are supported by previous findings from Novanda et al. (2024), who reported improved scientific argumentation skills among students using ethnoscience-based student worksheets (LKPD), with an N-gain of 0.6, high validity, and excellent practicality. This highlights the consistent effectiveness of the ethnoscience approach across various educational levels.

In addition to its effectiveness, the practicality of the teaching material was assessed through teacher and student response questionnaires. Teachers gave a score of 85%, while students provided a score of 84.8%, categorized as "very good" and "good," respectively. Teachers noted that the inclusion of concept maps or mind maps significantly aided students in understanding the structure of the material. Meanwhile, students stated that the material helped them comprehend the topics and was relevant to their everyday experiences.

Further statistical testing revealed that the gain score data followed a normal distribution ($p = 0.163$) according to the Shapiro-Wilk test. The Paired Samples t-Test yielded a t-value of -11.669 with a significance level of $p < 0.001$, indicating a statistically significant difference between pre-test and post-test scores. These results further reinforce the effectiveness of the developed teaching material.

Classroom observations also demonstrated the material's practicality. Indicators such as participation in discussions and the ability to express arguments were rated "good," while students' ability to relate physics concepts to local cultural phenomena was rated "very good." These findings suggest that the teaching material is not only easy to use but also capable of fostering active and contextual engagement in the learning process. This study was limited to a single school with a small sample; therefore, the generalization of the findings requires further research across multiple locations to ensure the effectiveness of the teaching materials in broader contexts.

In conclusion, the ethnoscience-based physics teaching material developed in this study proved to be valid, practical, and effective. The integration of local cultural contexts enables students to construct more relevant, logical, and contextual scientific arguments while enhancing their critical and analytical thinking skills. Therefore, this teaching material is recommended as an innovative alternative for physics learning that emphasizes not only conceptual mastery but also the development of higher order thinking skills, particularly in scientific argumentation.

CONCLUSION

This study developed ethnoscience-based physics teaching materials using the 4D model (Define, Design, Develop, Disseminate) by integrating local cultural wisdom to enhance students' argumentation skills. The materials were validated by media and content experts, obtaining feasibility scores of 75% and 83.3%, respectively, indicating that the materials are suitable for use with minor revisions. The trial results demonstrated high practicality, with teacher and student assessments of 85% and 84.8%, respectively. The teaching materials were also proven effective in improving students' argumentation skills, with an average gain score of 21.797, a symmetrical data distribution (skewness = -0.418), and normality (p = 0.163 on the Shapiro-Wilk test). The Paired Samples t-Test yielded a result of $t = -11.669$ and $p < 0.001$, indicating a significant difference between pre-test and post-test scores. The integration of local cultural contexts made physics concepts more relevant, meaningful, and applicable to students' daily lives.

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