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DEVELOPMENT OF ETHNOPHYSICS-BASED E-MODULE ON SOUND WAVES

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Abstract :
Physics education in Indonesia often struggles to present abstract concepts in a way that is easily understood and engaging, leading to learning difficulties among students. Integrating ethnophysics—contextualizing physics within local cultural practices and knowledge systems—offers a promising approach, especially in culturally rich regions. Sound waves, as a fundamental topic, provide opportunities for such integration through instructional modules. This study aims to evaluate the feasibility of an ethnophysics-based electronic module (e-module) on sound wave material through a research and development (R&D) approach. The development process followed the ADDIE model, limited to the stages of analysis, design, and development, and was followed by a limited-scale trial. Data were collected using expert validation sheets and student and teacher response questionnaires. Four validators participated, comprising two subject matter experts and two media experts. The limited-scale trial was conducted with 11th-grade students (class F-6) at SMA Negeri 1 Darul Imarah, Aceh Besar. The validation results indicated high validity, with expert scores of 0.81 (subject matter) and 0.87 (media). Content validity scored 0.86, construct validity 0.85, and language validity 0.66, yielding an overall score of 0.84—classified as highly valid. Student and teacher response rates were 84.8% and 90.3%, respectively, indicating strong practicality. These findings suggest that the developed ethnophysics-based e-module is both valid and practical, with strong potential to support culturally relevant and effective physics instruction.

Keywords: E-module, Ethnophysics, Sound Waves

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INTRODUCTION

Science education, including physics, plays a fundamental role in developing students' logical and analytical thinking skills. However, the reality in Indonesia shows significant challenges in achieving science skills. Based on data from the Programme for International Student Assessment (PISA) published by the Organization for Economic Co-operation and Development (OECD) in 2022, Indonesia was ranked 68th out of 80 countries. Although there was a slight increase in ranking from 2018, Indonesia's science ability score remains far behind, at 384 points, 101 points lower than the global

average score of 485 (OECD, 2022). This figure indicates that the level of science literacy and competence, including understanding of physics, of students in Indonesia is still in the low category.

One of the roots of this low achievement lies in the perception that physics is a complicated subject. This subject is less popular with most students in Indonesia (Siahaan et al., 2021). Physics is a branch of science that explains concepts, principles, laws, and theories of various natural phenomena closely related to human life (Erlangga et al., 2022) has great potential to develop students' experiences and competencies in understanding the surrounding environment. However, much empirical evidence shows that students still consider physics difficult (Batlolona et al., 2022). One example is the study by Nurhaniah et al., (2022), which measured the level of difficulty of physics for 11th-grade students at SMAN 3 Barru through diagnostic tests. The results showed that 78 out of 102 11th-grade students were in the very low and low categories. This difficulty arises not only from the demand for strong mathematical abilities but also because of the need for deep logical reasoning abilities to understand the abstract concepts of physics (Erlangga et al., 2022).

Observations and interviews with students and physics teachers at SMAN 1 Darul Imarah, Aceh Besar, reinforce the picture of students' difficulties in learning physics. A theoretical lecture approach still dominates the physics learning process at this school. Although teachers have attempted to relate the material to examples from students' daily lives, this contextual approach has not been optimally implemented. As a result, most students still face significant difficulties in understanding physics material, as evidenced by the majority of Mid-Semester Exam (UTS) results falling below the Minimum Competency Criteria (KKM). The limitations in applying the contextual approach necessitate the development of new, more relevant, and practical learning strategies.

Given the urgency of improving the quality of physics education, integrating local culture as a contextual strategy becomes highly relevant. Physics is a science that explains phenomena in everyday life (Wulandari et al., 2022), so its concepts can be explored through various local cultural phenomena (Festiyed et al., 2024). However, the practice of integrating local culture into physics education is still rarely found in educational practice. An educational approach integrated with local culture is called ethnoscience, while physics education based on local culture is known as ethnophysics. Ethnoscience is based on contextual knowledge derived from community concepts and practices, reinforced by cultural values, myths, and spiritual elements (Faqih et al., 2020). Thus, education is expected to facilitate students' understanding of the values and concepts within local culture, then align them with modern scientific knowledge (Festiyed et al., 2024).

Aceh Province, as one of the regions in Indonesia, with a very diverse cultural wealth (Nurmasyitah et al., 2022), holds tremendous potential as a source of physics learning. The physical and socio-cultural environment of the Acehnese community is rich in local wisdom, which can be explored through traditional musical instruments and games. Exploring this pluralistic and dynamic local wisdom can be a significant alternative source of knowledge in the teaching and learning process. Linking physics learning with local wisdom, as suggested by (Hartini et al., 2018a), is one effective strategy for creating more meaningful learning and encouraging deeper understanding. Furthermore, the Merdeka Curriculum in Indonesia also explicitly emphasizes the importance of a holistic, competency-based, and contextual approach that aligns with the characteristics of students and local culture (Kemendikbudristek, 2022; Festiyed et al., 2024). Ethnophysics-based learning has specifically been proven to enhance students' knowledge and understanding (Uge et al., 2019), empower conceptual understanding (Berardi, 2021), improve problem-solving skills (McLaughlin et al., 2018), and students' sustainable competencies (Lin et al., 2018). Therefore, the application of ethnophysics will facilitate students in learning various concepts, principles, and scientific materials in physics from contextual phenomena in real life, such as in the material on sound waves, which can be related to the traditional Acehnese game of seurune oen ue.

Seurune Oen Ue is a traditional Acehnese game resembling a flute-like musical instrument, crafted from coconut leaves, either young or mature, as its primary material. In its construction, the coconut leaves are rolled and twisted into a conical tube with a flared end resembling a funnel, which functions as the sound outlet. The crafting process requires precision to ensure the inner surface of the tube is smooth and gradually tapered, thereby producing optimal resonance. This game is played by blowing air through the narrow end, causing vibrations within the enclosed air column. These vibrations travel through the conical structure and are amplified at the flared end, producing a distinctive and bright

tone. Scientifically, this process can be explained through the principles of sound waves and acoustic resonance, making Seurune Oen Ue an ideal example for integrating ethnophysics into physics education.

The integration of local culture into physics education requires adequate instructional materials. Good instructional materials can help students master the material comprehensively (Hartini et al., 2018) and enable them to learn independently (Khuzaimah et al., 2022). With the development of information and communication technology, and in accordance with the mandate of Ministry of Education and Culture Regulation No. 22 of 2016 regarding standards for the process of basic and secondary education, which emphasizes the use of ICT for efficiency and effectiveness in learning (Najuah et al., 2020), the use of electronic modules (e-modules) has become a highly relevant solution in this digital age. E-modules have the advantage of incorporating various multimedia formats, making learning more interactive and less monotonous, and are highly suitable for Indonesian youth education by integrating local wisdom (Hartini et al., 2018). Interviews and observations at SMAN 1 Darul Imarah identified that although sound wave material modules are available, none integrate ethno-physics aspects. But, this e-module presents a novel approach by embedding ethnophysics perspectives—rooted in local cultural contexts, specifically the traditional Acehnese instrument *Seurune Oen Ue*—into the physics topic of sound waves, which has not been widely explored in existing instructional materials

Considering the complexity of the issues and the urgency previously outlined, the development of an ethnophysics-based e-module on sound wave material is deemed highly important. This study aims to evaluate the feasibility of the developed e-module as an instructional material in physics education at the secondary school level, assessing its validity and practicality. The integration of local cultural elements into physics learning is expected to bridge the gap between abstract scientific concepts and students' real-life experiences. The anticipated impact includes enhanced student engagement, improved conceptual understanding, and greater appreciation for local wisdom, thereby supporting contextual and meaningful learning in alignment with the principles of the Merdeka Curriculum.

RESEARCH METHOD

Research Design

This research is a Research and Development (R&D) that follows the ADDIE model development design, which consists of the stages of Analysis, Design, Development, Implementation, and Evaluation (Brunch, 2009).

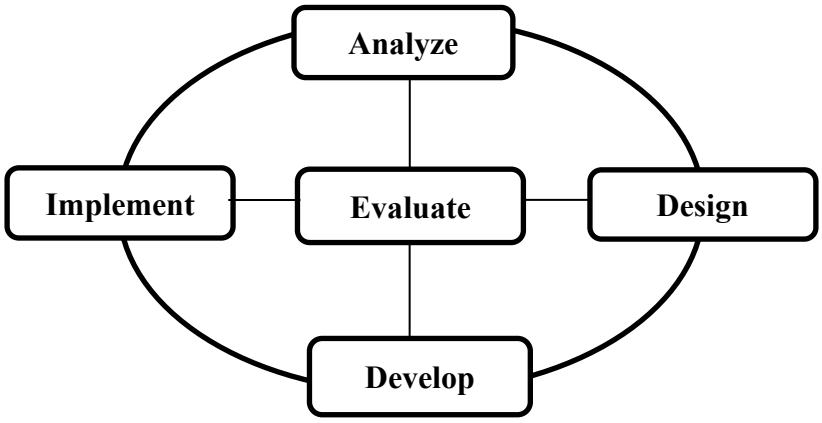

Figure 1. ADDIE Model

The ADDIE model was chosen because it aligns well with the principles of systematic instructional design. However, due to time constraints, this study was limited to the first three stages of the ADDIE model: analysis, design, and development. The ethnophysics-based e-module products developed using the ADDIE model were then tested for feasibility through product validity and practicality tests.

Research Target/ Subject

The subjects in this study were two subject matter experts and two media experts who are lecturers in their respective fields at the Faculty of Teacher Training and Education, Physics Department, University of Syiah Kuala, as well as the physics teacher and all 35 students in class XI F-6 at SMAN 1 Darul Imarah, Aceh Besar Regency.

Research Procedure

During the initial development stage, two key activities were conducted: a literature analysis and a needs analysis. Literature analysis was conducted by gathering various references in the form of articles and books that support the research and development of this e-module. Meanwhile, the needs analysis included an analysis of the curriculum, educators, students, and school facilities to produce an e-module that met the school's needs.

In the design stage, the e-module product was designed. The design consisted of the e-module's framework, structure, and components, as well as visual sketches and the materials and sound wave problems that would be included. Following the design phase, the process proceeded to the development stage. At this stage, the e-module was tested for validity, which involved validation by material experts and media experts, as well as validation of its content, construction, and language aspects. Once the e-module was declared valid, a usability test was conducted, involving evaluations by teachers and students to assess the ease of use of the developed e-module.

Instruments and Data Collection Techniques

This study aims to measure the feasibility of ethno-physics-based e-modules on sound wave material in terms of e-module quality. Therefore, the feasibility of these e-modules is reviewed from the aspects of validity and practicality. The research used non-test instruments, namely validation and practicality questionnaires. The validity test was conducted using expert validation sheets. These sheets were completed by two media experts and two material experts. The practicality test used response questionnaires distributed to one physics teacher and 35 grade XI F-6 students at SMAN 1 Darul Imarah. Although the instruments were designed based on the role of validators, each item of the media and material validity statements was also analyzed based on the aspects of content, construct, and language validity. The following is the outline of the expert validation sheet for materials and media, as well as the teacher and student response questionnaires, adapted from the research by Ramadanti et al., (2021).

Table 1 Media expert validation guidelines

No	Indicator	Item
1	Screen design appearance	1,2,3,4,5,6
2	Language suitability	7,8,9
3	Ease of use	10,11,12
4	Graphics	13,14,15,16,17,18, 19,20,21,22,23
5	Usefulness	24,25

Expert judgment on content ensures that the developed material is academically accurate, pedagogically relevant, and culturally contextualized.

Table 2. Subject matter experts' validation guidelines

No	Indikator	Item
1	Preliminary aspects	1,2
2	Learning aspects and content	3,4,5,6,7,8,9,10,11,12
3	Linguistic aspects	13,14,15
4	Evaluation aspects	16,17,18
5	Ethnophysics	19

Feedback from students plays a crucial role in refining the media, as it reflects the actual user experience and level of acceptance. Student responses are collected through a questionnaire focusing on design, content, and language.

Table 2 Student Response Questionnaire Guidelines

No.	Indicator	Item
1.	Design aspects	1,2,3,4,5
2.	Content aspects	6,7,8,9,10,11,12,13
3.	Linguistic aspects	14,15

Similarly, the teacher response questionnaire focuses on aspects of content quality, instructional quality, and technical quality.

Table 3 Teacher Response Questionnaire Guidelines

No.	Indicator	Item
1.	Content quality aspects	1,2,3,4,5
2.	Instructional quality aspects	6
3.	Technical quality aspects	7,8,9,10,11,12

The data collection process includes an analysis phase consisting of a needs analysis through observation and interviews with teachers at SMAN 1 Darul Imarah, as well as a literature analysis through a review of various literature sources. The design phase involves developing an e-module tailored to the school's needs and curriculum, based on data from the needs analysis phase. The development stage involves improvements based on the validation results from expert media and content validators. Following this, a limited pilot test was conducted in class XI F-6 at SMAN 1 Darul Imarah, comprising 35 students.

Data analysis technique

Data analysis of the validity test instrument was conducted by calculating the agreement index of validators and users using Aiken's index to determine the validity of the indicators and items. After obtaining the agreement index, the category of the index value will be decided. The results of the decision based on Aiken's index are contained in the following table by Retnawati (2016).

Table 5. Indeks Aiken`s

Interval	Category
$0 < V \leq 0{,}4$	Insufficiently Valid
$0{,}4 < V \leq 0{,}8$	Sufficiently Valid
$0{,}8 < V \leq 1$	Highly Valid

The practicality data of the media was obtained from questionnaires completed by teachers and students. The assessment criteria for the questionnaires used the achievement percentage formula in accordance with the assessment guidelines by Riduwan (2019).

Table 6. Percentage and categories of practicality

Percentage (%)	Category
0-20	Not practical
21-40	Not very practical
41-60	Quite practical
61-80	Practical
81-100	Very practical

RESULTS AND DISCUSSION

A. Analysis Stage

This stage involves a needs analysis and a literature review. A needs analysis was conducted through observation and interviews with physics teachers at SMAN 1 Darul Imarah, which included an analysis of the school curriculum, educators and students, and facilities. The results of the analysis indicate that the curriculum used in grades X-XI already employs the independent curriculum, but grade XII still uses the 13th curriculum. Teaching at the school remains teacher-centered, using lecture methods, and has never linked physics education to local culture. Furthermore, students face difficulties in understanding physics, tend to be passive, and lack interest in learning the subject. Finally, the teaching materials used at the school have not linked local culture to learning.

Literature analysis was conducted through the review and examination of various reference sources, including journal articles, books, and other references related to the development of e-modules based on ethnophysics on the topic of sound waves in high school physics education. The results of the literature analysis can be seen in the table below.

Table 7. Literature Review

No	Activity Aspect	Result	Source
1	The Importance of Ethnophysics in Learning	Can improve knowledge and understanding	Uge et al. (2019)
		Can empower students' conceptual understanding	Berardi (2021)
		Able to improve students' problem-solving skills	McLaughlin et al. (2018)
		Ethnophysics can encourage students' knowledge, skills, and competencies through a continuous learning process	Lin et al. (2018)
2	Ethnophysics-based E-module	As a means to empower and integrate ethnophysics into learning	Mahyudin & Hasan, (2024)
		makes it easier for students to understand learning and motivates them to learn	Lastri (2023)

B. Design

During the design stage, researchers developed a framework for the e-module based on the results of the previously conducted needs analysis and literature review. The framework was developed based on the main components of the module, as outlined in the guidelines of the Directorate of Senior High School Development, Directorate General of Primary and Secondary Education, Ministry of National Education (Diana et al., 2023) Namely: 1) the introductory section; 2) the core section; and 3) the concluding section.

The introductory section includes the preface, table of contents, learning menu, review of learning materials, and concept map. The main section contains an explanation of sound wave material accompanied by example questions, assignments, and summaries. This section also includes the integration of ethnophysics, specifically through the introduction of the traditional Acehnese game Seurune oen ue as a representation of the concept of sound waves within the local cultural context. Finally, the closing section consists of a formative test, a glossary, a bibliography, and the author's biography. The initial design phase began with compiling all e-module content using Microsoft Word 2019, designing storyboards, and creating visual sketches. Subsequently, the e-module was designed on the Canva platform to create an attractive, interactive e-module that supports the integration of multimedia elements.

Figure 2. Visual sketch design of the e-module and design results in Canva

C. Development Stage

The development stage assesses the feasibility of using the designed e-module, which is then validated by experts and practitioners in the field, as well as evaluated for practicality by teachers and students.

a) Validity Test

The validity test consists of subject matter experts' validation by two validators and media expert validation by two validators as well. This content validation is measured based on the alignment between the content in the e-module (sound wave content) and the Learning Outcomes (CP) in the Merdeka Curriculum at SMAN 1 Darul Imarah, Aceh Besar Regency. Media expert validation is used to assess the quality of the e-module's appearance, functionality, and technical feasibility. After the e-module was developed, it was provided to the validators. The following are some suggestions and feedback from the validation results.

Table 8. Suggestions from subject matter experts

Validator	Suggestions
Subject matter expert 1	16. Add questions related to seurune oen ue to the evaluation questions 18. Open access to answers for those who have the link
Subject matter expert 2	15. Correct the spelling of seurune oen ue to seurune oen ue, in accordance with the rules of writing 18. Integrate Seurune Oen Ue specifically into the material on open organ pipes

The suggestions provided by subject matter experts focus on refining the accuracy of terminology, integrating key concepts into specific materials, and ensuring accessibility for learners.

Table 9. Suggestions from media experts

Validator	Suggestions
Media expert 1	2. Reduce the amount of text in each topic so that students can easily understand the material and not get bored. 10. In the material review section, add an icon indicating that “this menu is a guide to using the module.” 11. Pay attention to the ABCs in Kahoot (adjust) and correct typos. 16. The text is quite dense, so summarize each sentence further. 18. Add illustrations to the example questions and reduce the number of example questions in each subsection. 19. There are several images/videos without cited sources.

	24. Sentence density can cause cognitive load. Revise.
Media expert 2	-

The input from media experts primarily addresses structural and presentation issues, such as reducing text density, enhancing readability, incorporating illustrative examples, and providing accurate source citations. After revisions were made to the suggestions and inputs, the validity of the e-module was reassessed. The following presents the validation results by material experts and media experts on the e-module that has been developed.

Table 10. Results of subject matter expert validation by validators I and II

Aspect	Score for each aspect	Total score	Category
Preliminary aspects	0,83		
Learning aspects and content	0,78	0,81	Highly valid
Linguistic aspects	0,72		
Evaluation aspects	0,94		
Ethnophysics	0,83		

The validation results from subject matter experts indicate that the developed material meets the required standards with an overall score of 0.81, categorized as highly valid. This shows that the content, language, evaluation, and ethnophysics aspects are appropriate and can be applied effectively in the learning process.

Table 11. Results of media expert validation by validators I and II

Aspect	Score for each aspect	Total score	Category
Screen design appearance	0,86		
Language suitability	0,83		
Ease of use	0,88	0,87	Highly valid
Graphics	0,87		
Usefulness	0,91		

The validation by media experts obtained a total score of 0.87, also falling into the highly valid category. This indicates that the media is well-designed in terms of screen appearance, language suitability, ease of use, graphics, and usefulness. Feedback from teachers and students further supports the practicality and usefulness of this approach in the learning process. Overall, the media is considered highly valid and can be effectively implemented in educational settings.

After the e-module was analyzed for feasibility based on validation by media and material experts, each item of the media and material validity statement was also analyzed based on the aspects of content, construct, and language validity. This is because, according to Arikunto (2013) and (Riduwan, 2015) the validity of a development product should encompass three aspects: content accuracy, structural presentation accuracy (construct), and clarity of language use. The following table presents the results of the analysis of the validation statements from the content, construct, and language aspects.

Table 12. Results of expert validation analysis based on content, construct, and language aspects

Aspect	Score for each aspect	Total score	Category
Content	0,86		
Construct	0,85	0,84	Highly valid
Language	0,66		

Based on the results from the content expert validation, media expert validation, and validation of aspects including content, construct, and language, it was found that the ethnophysics-based e-module developed is highly valid for use in physics education in schools. Where the subject matter expert validation scored 0.81, the media expert validation scored 0.87, and the content, construct, and language

aspects scored 0.84. Based on Aiken's V interpretation, these scores fall within the 'highly valid' category, indicating that the developed e-module demonstrates strong alignment with curriculum requirements, clear and coherent presentation of materials, and technically sound media design. Such high validity suggests that the e-module is not only appropriate for instructional use but also capable of facilitating accurate conceptual understanding and engaging learning experiences. Consequently, its integration into classroom practice is expected to enhance learning efficiency, reduce misconceptions, and promote deeper student engagement with the physics content.

Here are some sections of the e-module that have been developed and revised based on suggestions from validators.

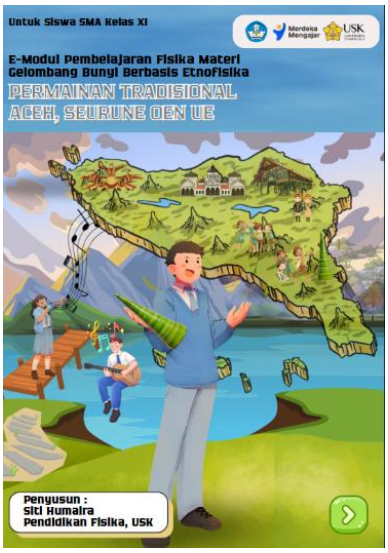

Figure 3. E-module cover

Figure 4 Main menu

Figure 5. Material menu

Figure 6. content

Figure 7. Integration of ethnophysics

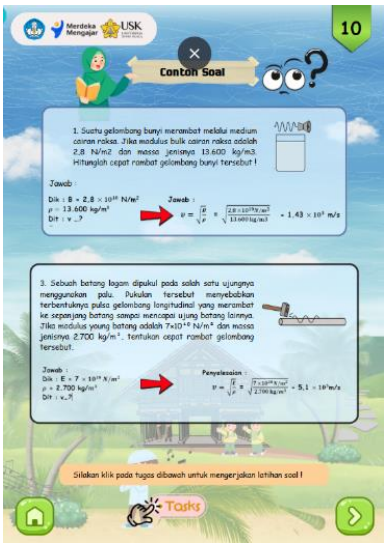

Figure 8. Sample question

In the main menu, students can select various options, including the Material menu, which displays a screen similar to Figure 4. In the learning menu (materials), students can select various materials, and after making a selection, screens like Figures 6 and 7 will appear. In each menu, to navigate to the following menu, students can press the icon, scroll to the right, or scroll to the left. After the validators validate the e-module following a series of revisions, it is then tested on a limited basis in class XI F-6. The purpose of this testing is to revise initial product errors and serve as a reference for improvements before proceeding to the implementation phase (Branch, 2009).

b. Practicality Test

After undergoing a validation process by experts, the developed e-module was then given to physics teachers teaching in grade XI and grade XI F-6 students at SMAN 1 Darul Imarah to assess its practicality through teacher response questionnaires and student response questionnaires. The practicality test was used to determine whether the developed product was easy to use and apply by others. In development research, Nieveen (2010) stated that the practicality criteria of a development product are assessed based on ease of use by teachers/students, clarity of instructions, ease of understanding the material/tasks/activities, and efficient use of time. These four practicality criteria are reflected in the teacher and student response questionnaire grids. The results of the teacher and student response questionnaire analysis are presented in the table below.

Table 13. Results of the teacher response questionnaire analysis

No	Assessment Aspect	Persentage
1	Content quality aspects	96 %
2	Instructional quality aspects	100 %
3	Technical quality aspects	90 %
	Average	95,3 %

The results of the teacher response questionnaire analysis show an average score of 95.3%, indicating that the developed media is highly effective in terms of content quality, instructional quality, and technical quality aspects.

Table 14. Results of the student response questionnaire analysis

No	Assessment Aspect	Persentage
1	Design aspects	85,6%
2	Content aspects	65,6%
3	Linguistic aspects	83,2 %
	Average	84,8%

The analysis of the student response questionnaire yielded an overall average of 84.8%. This result indicates that students considered the media to be good in terms of design, content, and language aspects, demonstrating its feasibility and acceptability from the learners' perspective. Based on teacher and student responses, confirm that the media are both effective and practical in supporting the learning process.

Therefore, by considering the research results alongside the various challenges in physics education—such as students' limited ability to understand physics concepts, persistent learning difficulties, the predominance of theoretical teaching approaches, and the lack of teaching materials integrating local culture—the development of an ethnophysics-based e-module on sound wave material may be regarded as a relevant and solution-oriented strategy. The high validity scores (0.81 for subject matter experts, 0.87 for media experts, and 0.84 for content, construct, and language aspects) suggest strong content accuracy, coherent structural organization, and sound technical design. In contrast, the high practicality scores (84.8% from students and 90.3% from the teacher) indicate that the module is user-friendly, engaging, and applicable in classroom contexts. Compared with previous studies (Hartini et al., 2018; Mahyudin & Hasan, 2024), which also demonstrated the potential of ethnophysics integration in science instruction, the present study further contributes by embedding local cultural practices into the teaching of sound waves, thereby reinforcing the relevance of this approach in diverse educational settings.

An analysis of the differing response rates between teachers and students revealed slightly higher enthusiasm from the teacher, which could reflect differences in professional perspectives, expectations, or familiarity with digital instructional materials. This variation should be taken into account during implementation to ensure balanced engagement from both educators and learners. In practical terms, the developed module could be employed not only in senior high school physics classes aligned with the Merdeka Curriculum but also adapted for extracurricular science clubs, local culture-

based STEM programs, or professional development initiatives focused on contextual instructional design.

Nevertheless, this research was limited to the analysis, design, and development stages of the ADDIE model, with only a small-scale trial conducted. Future studies should extend to the implementation and evaluation phases, involving larger and more diverse student populations, and incorporate more advanced interactive features—such as virtual laboratories, real-time feedback systems, and multimedia-based ethnophysics case studies—to further enhance learning outcomes and applicability.

CONCLUSION

The development of an ethnophysics-based e-module on sound waves has resulted in a valid and practical learning resource. Expert validation categorized the module as highly valid, while teacher and student responses indicated a high level of practicality, with average scores of 95.3% and 84.8%, respectively. These findings demonstrate that the e-module is not only feasible in terms of content and design but also well-received by users.

The study was limited to the development stage of the ADDIE model with a small-scale trial, and the current version lacks certain interactive features, complex illustrations, and comprehensive ethnophysical explanations. Future work should advance to large-scale implementation and evaluation, involving more diverse participants, and incorporate interactive elements such as direct answer input, virtual laboratories, dynamic animations, and advanced navigation menus. Additionally, it should consider modular development for more systematic coverage.

Overall, the findings show that culturally contextualized digital teaching materials can be both valid and practical, offering a promising approach to more meaningful, engaging, and outcome-oriented physics education.

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