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Development of Ethno-STEM Worksheets Using a Miniature Beduk and Arduino for the Sound Waves Unit

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ABSTRACT

The main challenge in teaching sound waves in physics is students' limited understanding of abstract concepts. This situation is exacerbated by the limited use of contextual learning media that integrate local culture with technology. To address this issue, this study aims to develop Student Worksheets (LKPD) based on the Ethno-STEM approach through the use of a miniature Beduk assisted by an Arduino system. The Research and Development (R&D) procedure, based on the 4D development model (define, design, develop, disseminate), formed the basis for this study. The evaluation involved two subject-matter experts, two media experts, a physics teacher, and 26 11th-grade students from State High School 8 in Jambi City during the limited pilot test phase. Student response questionnaires and expert validation forms served as data collection instruments. The analysis utilized Aiken's V formula, reliability tests, and descriptive percentages based on the Likert scale. The results showed that the worksheets achieved an Aiken's V value of 0.99 in subject matter expert validation and 0.98 in media expert validation, both falling into the "highly valid" category. Validation by educators yielded an average percentage of 96.17% (highly valid). The results of the instrument's reliability test showed a Cronbach's Alpha value of 0.889 (highly reliable). Additionally, student responses regarding the use of the worksheets reached a percentage of 80.62%, categorized as practical. These results indicate that the Ethno-STEM-based worksheets using an Arduino-integrated Beduk miniature meet the standards for validity and practicality in teaching the physics topic of sound waves. This study contributes to the advancement of physics instruction using the Ethno-STEM approach to support the implementation of the Merdeka Curriculum.

Keywords: Ethno-STEM; Worksheets; Arduino; Sound Waves; Beduk

INTRODUCTION

As a branch of science, physics plays a crucial role in honing students' logical, critical, and methodological thinking skills. However, the implementation of physics education in formal institutions still faces various tangible challenges, particularly when covering abstract topics such as sound waves. Based on preliminary observational data gathered through an interview with physics teacher Ms. RS, as well as a survey distributed to 26 eleventh-grade students at State High School 8 in Jambi City, it was revealed that the majority of students face significant difficulties in constructing an understanding of the essence of frequency, amplitude, resonance, and the speed of sound waves. This situation is exacerbated by classroom instructional activities that are still predominantly based on verbal delivery through lectures and the use of conventional textbooks,

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thereby limiting students' opportunities to gain direct practical experience. However, Nurrita (2018) emphasizes that the use of relevant learning media can effectively transform abstract concepts into concrete phenomena, thereby enhancing the efficiency of the learning process.

Previous research has shown that poor understanding of physics concepts is influenced by a lack of learning materials capable of linking abstract concepts to real-world phenomena. Hoerunnisa et al. (2024) state that students still struggle to understand abstract concepts and tend to memorize formulas. Additionally, Indah L & Hamdu (2022) found that teachers need instructional materials that align with curriculum requirements while being easy tso use in the classroom. To understand the context of this study, the state-of-the-art review must be systematically categorized into three research pathways. Research on STEM-based worksheets by Widiastuti and Priantini (2022) has demonstrated increased student participation through contextual activities, but most studies have not yet incorporated direct data-measurement technology into these activities. Second, studies on ethnoscience indicate that the context of local culture can effectively enhance science literacy; however, their development is typically limited to qualitative aspects, and few have investigated traditional instruments such as the beduk as subjects for quantitative experiments. Third, research on the use of Arduino technology in sound wave learning demonstrates a high level of accuracy in vibration measurement, but its implementation often fails to adequately consider the local sociocultural context. Based on this research map, a research gap has been identified that has not been addressed by previous studies: there is no analysis that comprehensively integrates these three elements into a single learning product.

The integration of the STEM (Science, Technology, Engineering, and Mathematics) framework emerges as a viable solution to meet the demands of 21st-century education due to its ability to correlate scientific theories with the application of technology and the resolution of real-world problems in the field. A review by Nugroho et al. (2019) confirms that the STEM approach has proven effective in enhancing critical thinking skills while stimulating students' creativity. Furthermore, the integration of Arduino technology into physics instruction provides students with the opportunity to conduct experiments independently, which in turn successfully makes the laws of physics more tangible and easier to internalize. In fact, the application of piezoelectric sensors supported by the Arduino system has been proven capable of accurately measuring vibrations and sound frequencies.

On the other hand, the integration of local culture into physics education remains very limited. Yet, local culture can serve as a meaningful learning context for students. The beduk was specifically chosen as a local cultural context in Jambi because it plays a central role in community life, particularly in mosques and suraus as a signal for prayer times and in various traditional Malay Jambi events. When played, the beduk produces sound through strikes with a special mallet on its leather membrane. The advantage of using a mini beduk in physics instruction lies in the concept of sound waves that students can observe directly, such as studying vibrations in the membrane (amplitude), observing variations in pitch resulting from differences in striking force (frequency), and analyzing the reverberation effect produced by the beduk's tubular cavity (resonance).

As a traditional instrument of Indonesian society, the beduk is closely linked to the concept of sound waves and can therefore be utilized as a medium for ethno-science-based physics education. Socrates et al. (2023) state that the integration of ethno-science into physics education can enhance science literacy while strengthening appreciation for local culture. However, there has been little research developing ethno-STEM-based worksheets using Arduino-assisted physical media within the local cultural context of Jambi. This situation indicates a research gap that requires further investigation. Fauzi et al. (2024) reveal that students' learning motivation and character are key elements in the success of physics learning. Furthermore, previous studies have generally focused only on the development of STEM-based worksheets or the integration of local culture separately; consequently, there are still few studies that combine local culture, Arduino technology, and the Ethno-STEM approach into a single comprehensive learning product. Therefore, there is a need for learning tools that are not only academically sound but also capable of enhancing student participation through contextual and meaningful activities.

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The novelty of this study lies in the integration of the local Beduk culture as an ethnoscience context, the use of Arduino technology and piezoelectric sensors as experimental tools, and the application of the Ethno-STEM approach in a single worksheet product on the topic of sound waves. The integration of these three elements aims to provide a contextual, inquiry-based learning experience aligned with the implementation of the Merdeka Curriculum.

METHOD

This study employed the Research and Development (R&D) method using the 4D development model, which consists of the Define, Design, Develop, and Disseminate stages. The 4D development model was introduced by Thiagarajan et al. (1974) and is frequently used in research on the development of learning tools because it produces structured products of proven quality. According to Creswell and Clark (2023), research and development is a method that combines quantitative and qualitative approaches to produce products that are valid and suitable for application in learning practices. This model was chosen because it is capable of producing systematic learning tools that have been tested for feasibility.

This study was conducted at Jambi State High School No. 8 during the 2025/2026 academic year. The research location was determined using purposive sampling, based on the consideration that laboratory instruments utilizing microcontroller technology were not yet available at this school. Additionally, the school is actively implementing the Merdeka Curriculum. The parties involved as subjects in this study included two evaluators for content validation, two practitioners serving as learning media assessors, a physics teacher, and 26 11th-grade science students from State High School 8 in Jambi City who acted as participants in the small-scale product testing phase.

The sample selection procedure for the student group was based on the purposive sampling method. The selection took into account the heterogeneity of academic ability within the class, which included high, medium, and low achievement categories. Another consideration was that the study group had not yet engaged in an in-depth discussion of the topic of sound waves. These characteristics made the class suitable for assessing the initial practicality of the developed product.

The *"define"* phase was carried out through a needs analysis, curriculum analysis, analysis of student characteristics, and analysis of sound wave material. The "design" phase included the design of ethno-STEM-based worksheets, the creation of research instruments, and the development of a miniature Beduk using an Arduino. Specifically, the hardware design in this phase utilizes key components such as a miniature Beduk (made of wood and a goatskin membrane), an Arduino Uno microcontroller, a piezoelectric sensor mounted on the membrane to detect vibrations, and a laptop running the Arduino IDE as the output display. The physical variable to be measured is the sound frequency produced by the speaker when the beduk membrane is struck with varying pressure. To ensure the validity of the data, the device was calibrated by comparing the frequency readings on the Arduino's LCD screen with a reference measurement tool a verified sound frequency analyzer app on a smartphone. The data generated by this system consists of numerical frequency values (in Hertz) displayed in real time. The development phase involved validation by experts, product revisions, and limited testing with students. The deployment phase was conducted on a limited scale by introducing and testing the product with physics teachers at a research school.

The miniature Beduk was designed using a piezoelectric sensor connected to an Arduino Uno as the data processor. The piezoelectric sensor detects vibrations generated when the surface of the miniature Beduk is struck; the resulting signal is then processed by the Arduino to display the sound frequency data. Before being implemented in the classroom, the device's functionality was tested to ensure all components worked properly and could display measurement data in accordance with the learning objectives.

The research instruments were classified into two categories based on their functions. First, instruments for assessing product quality, consisting of an interview sheet, a subject matter expert validation sheet (18 statements), and a media expert validation sheet (34 statements). Second, instruments for measuring student responses in the form of a practicality questionnaire (25

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statements). All of these statement instruments use a 4-point Likert scale (scores 1 through 4). The subject matter expert validation sheet assesses content appropriateness (indicator: accuracy of wave equations in the context of the beduk), STEM integration (indicator: clarity of the engineering process in assembling sensors), and linguistic aspects. Meanwhile, the media expert validation sheet assessed visual design, layout (indicator: appropriate placement of the Arduino circuit diagram), and readability. The student response questionnaire assessed practicality (indicator: ease of reading the frequency output) and appeal.

Product validity was analyzed using Aiken's V formula, while instrument reliability was analyzed using Cronbach's Alpha.

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\Sigma\sigma_i^2}{\sigma_t^2}\right) \quad (1)$$

Notes:
α = Cronbach's Alpha coefficient
k = Number of items
σ^2_i = Variance of the i-th item score
σ^2_t = Variance of the total score

Instrument reliability was assessed by calculating the Cronbach's Alpha coefficient to measure the degree of internal consistency of the research instrument used. The instrument's reliability is directly proportional to the Cronbach's Alpha score obtained, with higher scores indicating a stronger level of consistency. Meanwhile, to explore student feedback, data were calculated based on the percentage of achievement derived from the Likert scale conversion. The entire data processing procedure utilized quantitative descriptive techniques to assess the degree of validity and the practicality of the developed instrument.

It is important to distinguish that instrument validity (which ensures that the questionnaire actually measures what it is intended to measure) is determined through expert assessment during the development process, whereas product validity (which evaluates the suitability of the worksheets and the drum-Arduino device) is calculated using Aiken's V formula. The interpretation categories for Aiken's V are divided into: <0.40 (invalid), 0.40-0.80 (moderately valid), and >0.80 (highly valid). On the other hand, the reliability of the student response questionnaire was analyzed using Cronbach's alpha to evaluate the internal consistency of the statement items presented to the students.

RESULTS AND DISCUSSION

The final product successfully developed in this study is the Ethno-STEM Worksheet focused on sound waves and integrated with a miniature Beduk teaching aid that uses Arduino. Structurally, this worksheet consists of a cultural context introduction, learning objectives, instructions for using the tool, an exploration activity sheet, an observation sheet, data analysis, and a learning reflection. The STEM activity sequence within it is designed in detail through the following steps: (S) Science, in which students observe wave principles in the Beduk; (T) Technology, in which they operate the Arduino microcontroller system; (E) Engineering, in which they design variations of striking experiments on the Beduk; and (M) Mathematics, in which they analyze quantitative data from measurements. In practice, students strike the miniature drum, and a piezoelectric sensor attached to the membrane captures the vibrations and sends a signal to the Arduino. As a result of the measurement, the Arduino processes these vibrations and displays the sound frequency value directly in Hertz (Hz) on the LCD screen, allowing students to visualize the otherwise invisible concept of sound waves through quantitative data.

The development of this final product was the result of refinement through the 4D model. During the *"define"* phase, initial findings revealed that physics instruction at State High School 8 in Jambi City was still dominated by lecture-based methods and the use of textbooks, causing students to struggle with understanding the abstract concept of sound waves. Based on these findings, during the design phase, the worksheet was created by integrating the four elements of STEM. The miniature Beduk drum serves as a local cultural context, while the Arduino and

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piezoelectric sensors are used to support students in taking measurements. The integration of local culture, technology, and the STEM approach in this initial design aims to create a relevant learning experience and encourage active student engagement before the product is validated in the next step.

Expert validation of the material was conducted in two stages to ensure that the developed worksheet met the criteria for content appropriateness, language, presentation, and STEM integration. The first stage examined the initial quality of each component and identified sections that required refinement. The validators assessed whether the sound-wave content was scientifically accurate, whether the learning activities reflected the STEM framework, and whether the language was appropriate for students. Their quantitative ratings were interpreted together with written suggestions so that the revision process was based on both scores and specific recommendations. The second stage then verified the quality of the worksheet after the recommended changes had been implemented. This staged validation process provided a systematic basis for determining the readiness of the material for classroom use.

Table 1. Results of Phase I Content Validation

No	Assessment Aspect	Aiken's V	Percentage	Category
1.	Content	0.90	92.5	Highly Valid
2.	Integration of STEM and Pedagogy	0.83	87.50	Highly Valid
3.	Language and Readability	0.91	97.35	Highly Valid
	Average	**0.88**	**92.45**	**Highly Valid**

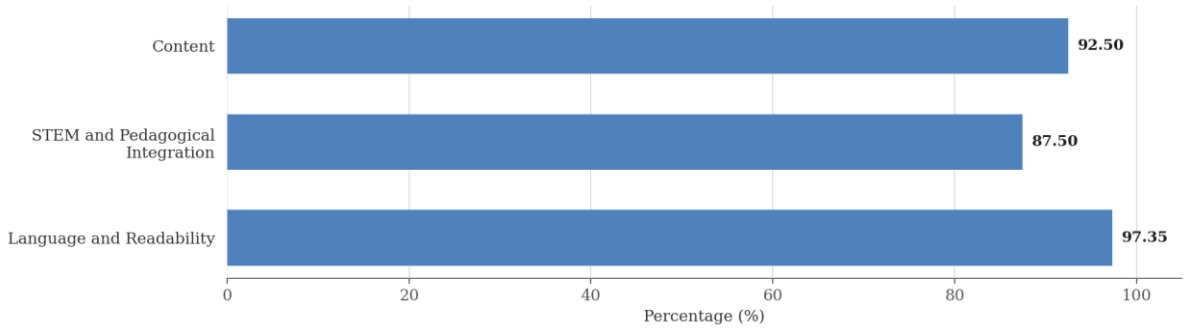

Figure 1. Percentage of Phase I Content Validation

Phase I content validation yielded an average Aiken's V score of 0.88 with a validity percentage of 92.45%, placing it in the "highly valid" category. Nevertheless, the validators provided several recommendations for improvements regarding content, language use, and STEM integration to refine the worksheets. These results indicate that, overall, the materials provided in the worksheets align with the learning outcomes, student characteristics, and the intended learning objectives. The high level of validity indicates that the elements of Science, Technology, Engineering, and Mathematics have been well integrated into the designed learning activities. However, feedback from the validators is still needed to improve the quality of the product before proceeding to the next validation stage, so that the developed worksheets become more effective for use in physics instruction.

Table 2 summarizes the Phase I validators' suggestions and the revisions implemented before Phase II. For the content aspect, the explanation of resonance was strengthened by adding a clearer description and contextual examples. For the language aspect, sentence construction was revised to improve accuracy and readability in accordance with PUEBI. For STEM integration, the engineering activities were clarified by adding explicit experimental design stages. These revisions directly addressed the weaknesses identified in the initial assessment rather than changing the main structure of the worksheet. The revised material was subsequently submitted for the second validation stage to determine whether its quality had improved.

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Table 2. Validator Suggestions and Revisions

Aspect	Validator's Suggestions	Revisions
Content	Clarify the concept of resonance	Added an explanation of resonance and contextual examples
Language	Sentence corrections	Aligned with PUEBI
STEM	Engineering activities clarified	Added experimental design stages

After the Phase I recommendations had been addressed, the revised material was evaluated again in Phase II. The second assessment used the same three aspects to allow direct comparison with the initial results. This revalidation focused on whether the revisions improved content accuracy, STEM and pedagogical integration, and readability. The outcomes of the second assessment are presented in Table 3.

Table 3. Results of Phase II Content Validation

No	Assessment Aspect	Aiken's V	Percentage	Category
1.	Content	0.98	98.75	Highly Valid
2.	Integration of STEM and Pedagogy	1.00	100	Highly Valid
3.	Language and Readability	1.00	100	Very Valid
	Average	**0.99**	**99.58**	**Highly Valid**

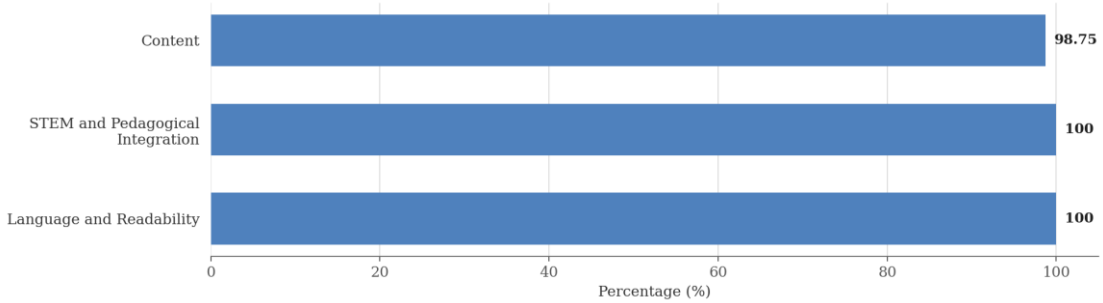

Figure 2. Percentage of Phase II Content Validation

Figure 2 shows that the Phase II subject matter expert validation produced an average Aiken's V value of 0.99 and an average percentage of 99.58%, both of which fall within the highly valid category. The content aspect reached 98.75%, while STEM and pedagogical integration and language and readability each reached 100%. Compared with Phase I, the average Aiken's V value increased from 0.88 to 0.99, and the average percentage increased from 92.45% to 99.58%. This improvement indicates that the revisions based on the validators' suggestions addressed the weaknesses identified during the initial assessment. The consistently high scores across the three aspects also show that the revised worksheet achieved a balanced level of quality in content, instructional design, and readability. Therefore, the Phase II results provide stronger evidence that the material is suitable for use in physics instruction.

The results show that the implemented changes successfully improved the quality of the content, STEM integration, and the readability of the worksheets. This study aligns with the findings of Kiswari et al. (2022), which indicate that STEM-oriented worksheets can enhance students' conceptual understanding through more structured and relevant learning activities. These findings are also supported by Ulya et al. (2023), which demonstrate that STEM-based learning tools on the topic of waves effectively improve students' conceptual understanding and thinking skills.

The results of this study are also consistent with the perspective of Jantung (2021), who states that the development of well-structured worksheets can improve the quality of the instructional process because they stimulate students to construct their understanding of the material without relying entirely on the educator. The high validation score demonstrates that the information content within the LKPD is appropriately integrated with the learning objectives, student profiles, and the principles of STEM-based education. Based on the scores obtained in the second phase of

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evaluation, the LKPD set has been proven to meet the standards for substantive quality. This document can be used as a relevant instructional resource for teaching the topic of sound waves.

Media expert validation was conducted in two stages to evaluate the presentability and technical quality of the developed learning media. The assessment examined the completeness of the LKPD components, cover design, layout and typography, graphics, presentation of student activities, and visual readability. Phase I was intended to identify design elements that could hinder students when reading instructions or carrying out activities. The validators' ratings were reviewed together with their comments regarding color contrast, spacing, image placement, and navigation. The worksheet was then revised and reassessed in Phase II using the same evaluation aspects. This procedure enabled the study to document changes in media quality after the recommended design improvements were applied.

Table 4. Results of Phase I Media Validation

No	Evaluation Aspect	Aiken's V	Percentage	Category
1.	LKPD Components	0.97	97.92	Highly Valid
2.	Cover Design	0.76	82.50	Highly Valid
3.	Layout & Typography (Content)	0.91	93.75	Highly Valid
4.	Content Display & Graphics	0.91	93.75	Highly Valid
5.	Presentation of Student Activities	1.00	100	Highly Valid
6.	Language (Visual Readability)	0.90	92.50	Highly Valid
	Average	**0.91**	**93.75**	**Highly Valid**

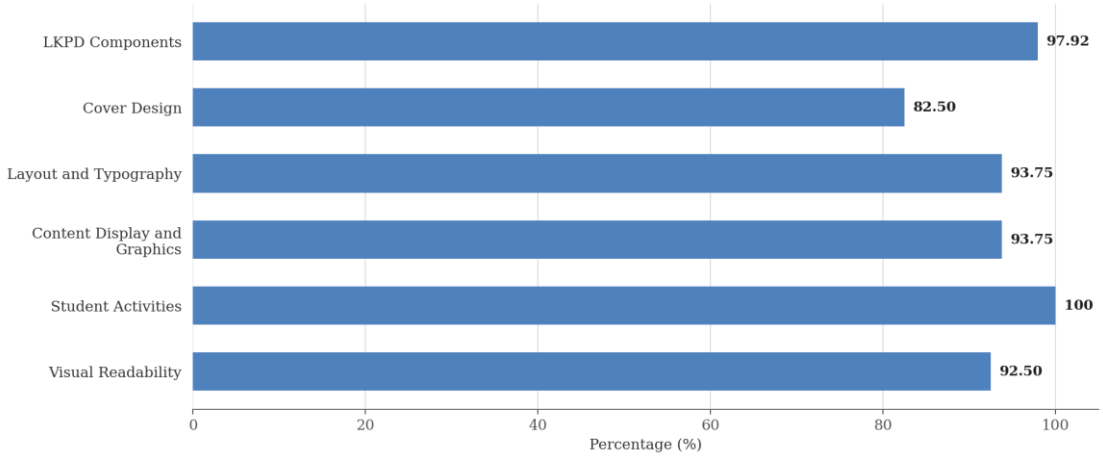

Figure 3. Percentage of Phase I Media Validation

Figure 3 indicates that the Phase I media expert validation produced an average Aiken's V value of 0.91 and an average percentage of 93.75%, placing the product in the highly valid category. The presentation of student activities received the highest score of 100%, whereas cover design obtained the lowest score of 82.50%. The remaining aspects ranged from 92.50% to 97.92%, showing that most elements already met the expected media quality criteria. Nevertheless, the comparatively lower score for cover design signaled a need to strengthen visual appeal and consistency. The validators also recommended improvements in typographic readability, white-space arrangement, and the placement of the Arduino circuit diagrams so that students could follow the worksheet more easily. Thus, the Phase I results established a strong initial level of feasibility while still providing clear priorities for revision.

After the Phase I media revisions were completed, the worksheet underwent Phase II media validation. The second assessment examined the same six aspects so that changes could be compared consistently. Particular attention was given to whether the revisions improved visual organization, typography, graphics, activity presentation, and readability. Table 5 presents the results of this follow-up media assessment.

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Table 5. Results of Phase II Media Validation

No	Evaluation Aspect	Aiken's V	Percentage	Category
1.	LKPD Component	1.00	100	Highly Valid
2.	Cover Design	1.00	100	Very Valid
3.	Layout & Typography (Content)	1.00	100	Highly Valid
4.	Content Display & Graphics	0.94	95.83	Highly Valid
5.	Presentation of Student Activities	1.00	100	Highly Valid
6.	Language (Visual Readability)	0.96	97.50	Highly Valid
	Average	**0.98**	**98.8**	**Highly Valid**

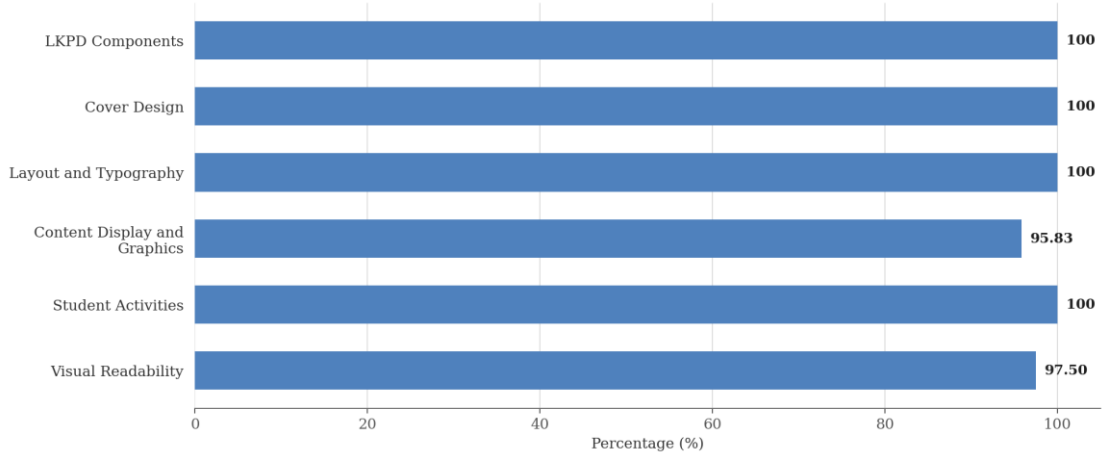

Figure 4. Percentage of Phase II Media Validation

The diagram in Figure 4 shows that the results of the Phase II media expert validation achieved an average Aiken's V score of 0.98, corresponding to a percentage of 98.8%, thereby falling into the "highly valid" category and suitable for use in physics instruction. The improvement in validation results in Phase II indicates that the modifications made based on feedback from validators through the application of more effective visual design principles, such as increased color contrast, clear image labeling, and a more structured navigation flow for the lab instructions successfully enhanced the visual quality and presentation of the worksheets significantly.

These data confirm that this LKPD product has met the standard qualifications in terms of visual aesthetics, which include optimal text readability, harmonious layout proportions, and a systematic workflow for students. Furthermore, the integration of explanatory images and technical diagrams illustrating the assembly procedures for the Arduino-sensor-equipped miniature drum played a crucial role in minimizing students' cognitive load, thereby ensuring the practicality of the learning material throughout the experimental activities. This empirical finding reinforces the study which revealed that the use of Arduino-based learning media can help students understand physics concepts more clearly during laboratory sessions, as it is accompanied by easy-to-follow diagrams.

The visualization of abstract physics concepts has proven to be more concrete and easier for students to understand through the use of interactive learning media supported by representative graphics on the topic of waves, as demonstrated in the research by Cahyanto et al. (2022). In line with this, educational tools that integrate the STEM framework can enrich students' learning experiences through interactive activities that are student-centered (Rahmi et al., 2022). Based on these considerations, the visual configuration, design layout, and readability of this worksheet meet the standard criteria for an ideal learning medium to optimize the efficiency and effectiveness of physics education in the classroom.

Educator validation was conducted to assess the extent to which the worksheets can support physics learning in schools. The assessment covered both the accuracy and relevance of the content and the quality of the media presentation. Educators evaluated the worksheet from the perspective of classroom implementation, including its alignment with learning objectives, clarity of activities, and ease of use. Their responses were important because they reflected practical considerations that may not be fully captured by subject matter and media experts. The content and media results were

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analyzed separately so that strengths and areas requiring improvement could be identified more precisely. Together, these assessments provided evidence of the product's suitability for use by teachers and students in an actual learning setting.

Table 6. Results of Content Validation by Educators

No	Evaluation Aspect	Percentage	Category
1.	Content	97.50	Highly Valid
2.	Integration of STEM and Pedagogy	100	Highly Valid
3.	Language and Readability	100	Very Valid
	Average	**99.17**	**Highly Valid**

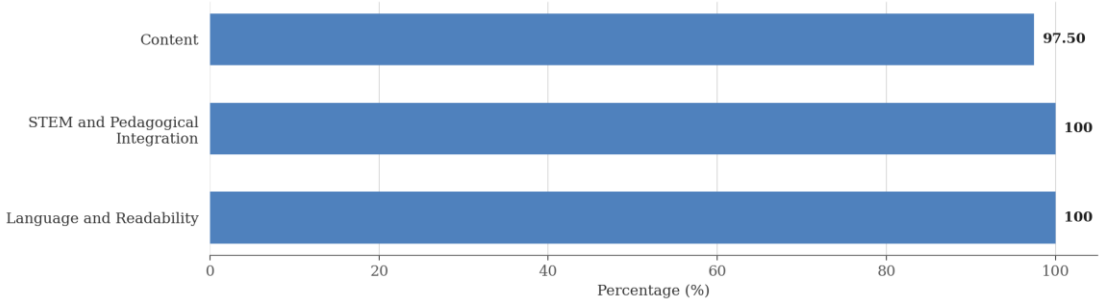

Figure 5. Percentage of Content Validation by Educators

Based on educators' assessments, the developed worksheet achieved an average content-validation score of 99.17%, placing it in the highly valid category. The integration of STEM and pedagogy and the language and readability aspects each obtained 100%, while the content aspect reached 97.50%. These scores show that educators considered the material closely aligned with the school curriculum and appropriate for supporting classroom instruction. Educators nevertheless provided corrective notes on several details to ensure that the worksheet could be implemented smoothly in different classroom conditions. The balanced integration of learning objectives, student activities, and the Ethno-STEM approach was identified as an important strength of the product. Overall, the educator assessment confirms that the worksheet has a strong substantive foundation for physics learning.

After completing the content assessment, educators also evaluated the media aspects of the worksheet. This evaluation considered the completeness of the LKPD components, cover design, layout and typography, graphics, presentation of student activities, and visual readability. Examining these aspects separately helped identify whether the product was sufficiently clear and practical from a teacher's perspective. The results of the educator media validation are presented in Table 7.

Table 7. Results of Media Validation by Educators

No	Evaluation Aspect	Percentage	Category
1.	LKPD Components	79.17	Highly Valid
2.	Cover Design	80.00	Very Valid
3.	Layout & Typography (Content)	100	Very Valid
4.	Content Display & Graphics	100	Very Valid
5.	Presentation of Student Activities	100	Highly Valid
6.	Language (Visual Readability)	100.00	Very Valid
	Average	**93.19**	**Highly Valid**

Figure 6 shows that teachers' media validation produced an average score of 93.19%, placing the worksheet in the highly valid category. The layout and typography, content display and graphics, presentation of student activities, and visual readability each reached 100%. The LKPD components and cover design obtained 79.17% and 80.00%, respectively, and therefore represented the main areas requiring further refinement. Despite these differences among aspects, the overall result indicates that educators regarded the worksheet as appropriate for classroom use. The high scores for presentation and readability suggest that the sequence of activities and supporting visuals can be followed clearly during instruction. Accordingly, the educators' evaluation supports the

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feasibility of the worksheet while also identifying specific design elements that should receive continued attention.

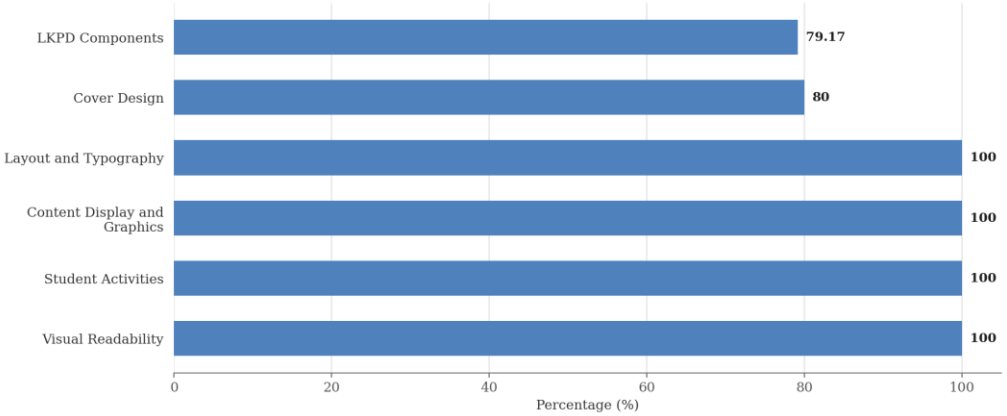

Figure 6. Percentage of Media Validation by Educators

This finding supports the study by Indah and Hamdu (2022), which revealed that educators require learning tools that align with the curriculum, are easy to use, and can support teaching and learning activities in the classroom. In the present study, this requirement is reflected in the high educator ratings for layout, presentation, readability, and classroom usability. The result also indicates that feasibility depends not only on an attractive appearance but also on the clarity of instructions and the organization of student activities. By combining these elements, the worksheet can support teachers in guiding students through contextual sound-wave investigations. Therefore, the educator response provides practical confirmation that the product design is compatible with the needs of classroom instruction.

The positive response from teachers confirms that the developed LKPD successfully accommodates all aspects of instructional needs within the school environment. This observation reinforces the study by, which states that STEM-oriented learning tools combined with local contexts consistently receive high appreciation from educators because they are deemed capable of facilitating a more relevant learning process. Furthermore, the Arduino-based Beduk miniature model is capable of creating a far more contextual learning experience by bridging the gap between physics theory and local traditions that are familiar to students' social environments.

Results from a limited pilot test indicate that students responded positively to the worksheets that were developed. Student feedback was used to assess the practicality of the product after its use in the learning process. The evaluation focused on ease of use, language and visual readability, activity implementation, and students' perceptions of the benefits and appeal of the worksheet for the sound-waves unit. The responses therefore describe the extent to which students could understand the instructions, complete the activities, and use the supporting media. These data indicate students' acceptance of and ease in using the worksheet during the pilot implementation. However, the responses were not analyzed as evidence of effectiveness in improving learning outcomes or conceptual understanding.

The student response data were summarized to describe the practicality of the worksheet across the five assessed aspects. Each percentage represents students' ratings of ease of use, language readability, visual readability, activity feasibility, and benefits and appeal. The average percentage was used to determine the overall practicality category of the product. Table 8 presents the complete distribution of student response results.

Table 8. Student Response Results

No	Assessment Aspect	Percentage	Category
1.	Practicality (Ease of Use)	80.19	Practical
2.	Readability (Language)	82.31	Practical
3.	Readability (Visual)	80.96	Practical
4.	Feasibility (Activities)	77.50	Practical
5.	Benefits & Appeal	82.12	Practical
	Average	**80.62**	**Practical**

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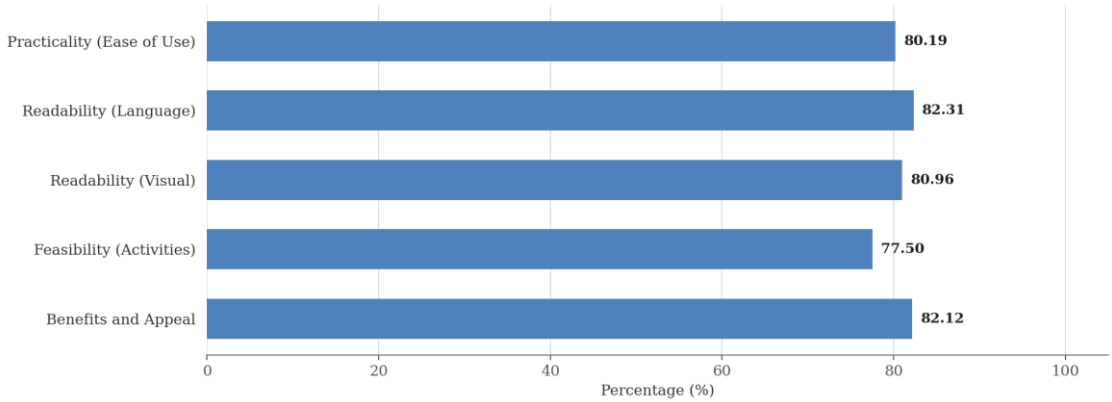

Figure 7. Student Response Questionnaire Results

The diagram shown indicates that the results of the student response questionnaire reached an average percentage of approximately 80.62% in the practical category. The percentage of student responses in the practical category indicates that the worksheets are easy to apply and received positive feedback from students during the learning process. This figure shows that students were able to use the worksheets effectively and follow each step of the designed learning activities. The high level of practicality also indicates that the language, visual presentation, usage instructions, and learning activities in the worksheets are well understood by the students. These findings suggest that the worksheets are well-received as a teaching tool, although it cannot yet be concluded that there is an increase in learning interest or understanding of sound wave concepts, as this study did not directly measure those two aspects.

The use of media and learning instruments that are both engaging and adaptable to students' characteristics has been shown to have a strong correlation with their learning experiences and motivation, as emphasized by Ahzari et al. (2025). In another dimension, the integration of scientific concepts with local culture which is closely tied to students' daily realities through EthnoSTEM-based learning is capable of boosting their science literacy (Bramastia et al., 2023). This theoretical framework aligns with field data demonstrating that the implementation of Ethno-STEM student worksheets (LKPD) featuring a miniature Beduk drum and supported by Arduino technology received a very positive response from students.

Empirically, students felt assisted in mastering sound wave material thanks to the practicality and appeal of these Ethno-STEM-based student worksheets featuring miniature Beduk drums integrated with Arduino technology. This phenomenon aligns with the perspective of that the incorporation of technological aspects into the educational process effectively enhances digital proficiency, boosts productivity, and fosters students' collaborative skills. Furthermore, Socrates et al. (2023) demonstrate that the reconstruction of local culture in the form of ethoscience in physics education successfully strengthens science literacy and creates a far more meaningful learning atmosphere. The integration of STEM with local wisdom, specifically on the topic of sound waves, is also acknowledged by Musyaddad and Pathoni (2025) as capable of boosting student motivation and fostering active engagement in the classroom. Based on this body of evidence, constructive feedback from students confirms that this worksheet not only meets media quality standards but also successfully transforms physics learning into a more contextual experience through the collaboration of science, technology, and culture.

Table 9. Reliability Test Results for Student Responses

Statistic	Value
Cronbach's Alpha	0.889
Number of Items	25
Number of Respondents	26

To determine whether the student response questionnaire produced consistent measurements, the instrument was analyzed using Cronbach's Alpha. The calculation was based on responses from the students who participated in the limited trial. The analysis focused on the

internal consistency of the 25 questionnaire items used to assess product practicality. The reliability results are presented in Table 9.

The reliability test of the student response questionnaire yielded a Cronbach's Alpha coefficient of 0.889, which indicates a very high level of internal consistency. The analysis involved responses from 26 students to an instrument containing 25 items. According to Tavakol and Dennick (2011), a reliability coefficient close to 1 indicates that the measurement instrument has strong internal consistency. This result shows that the questionnaire items produced responses that were sufficiently consistent across the measured aspects. Consequently, the instrument is appropriate for collecting students' views regarding the practicality of the developed worksheet. The reliability result strengthens confidence in the consistency of the response data used in the practicality analysis, although it does not by itself establish instrument validity.

The overall research results indicate that the Ethno-STEM-based worksheet supported by an Arduino-equipped miniature Beduk meets the criteria for validity and practicality, making it suitable for physics instruction on sound waves. The high validation scores from subject matter experts, media experts, and educators show that the product fulfills the expected standards for content, language, presentation, and Ethno-STEM integration. Student responses in the practical category further indicate that the worksheet can be used and understood during the learning activities. The agreement among these different groups of assessors strengthens the evidence that the product is ready for use within the scope of the limited trial. The findings also show that the local cultural context and the Arduino-based measurement activity can be integrated within a coherent worksheet structure. Nevertheless, these validity and practicality results should be distinguished from evidence of instructional effectiveness, which requires further testing of learning outcomes.

This study demonstrates that the integration of local culture and simple technology can serve as an innovative approach in physics education. The use of a miniature Beduk drum as a symbol of Jambi's local culture provides students with the opportunity to understand physics concepts through phenomena familiar to them in their daily lives. On the other hand, the integration of Arduino instruments with piezoelectric sensors allows students to conduct observations and measurements independently. This hands-on approach transforms classroom dynamics into a more active, dynamic, and meaningful learning experience for students.

Nevertheless, this study still faces limitations because the product trial was conducted only on a limited scale with 11th-grade students at SMA Negeri 8 in Jambi City. Furthermore, this study has not assessed the extent to which the worksheet is effective in improving students' learning outcomes or critical thinking skills. This study also has not evaluated the effectiveness of the worksheets in improving students' conceptual understanding of sound waves; consequently, the findings focus solely on the validity and practicality of the designed product. Therefore, it is recommended that future research evaluate the effectiveness of the worksheets on a larger scale and across different physics topics. Follow-up studies could also examine the impact of using the worksheets on students' academic achievement, mastery of sound wave concepts, and critical thinking skills. Future research could also develop similar products by incorporating other forms of local wisdom, thereby expanding the application of the Ethno-STEM approach in physics instruction.

CONCLUSION

A set of student-centered learning materials that integrates the Ethno-STEM approach through the use of an Arduino-based miniature Beduk has been successfully developed to facilitate learning about sound waves. Based on the evaluation process, the subject matter evaluator assigned an Aiken's V index score of 0.99, which falls within the "highly valid" criterion, and the media evaluator assigned an Aiken's V score of 0.98, also meeting the same high criterion. Assessments conducted by education practitioners or teachers indicated a 99.17% achievement rate for content review and a 93.19% rate for the media dimension, both of which fall within the "highly valid" category. From the user's perspective, the student response questionnaire yielded a suitability percentage of 80.62%, reflecting its practical nature, further supported by reliability results showing a Cronbach's Alpha coefficient of 0.889, indicating a very strong level of reliability.

This set of data demonstrates that the design of this worksheet meets the criteria for validity and practicality, making it suitable for use as an alternative teaching material in physics classes, particularly for the topic of sound waves. Academically, this research makes a tangible contribution to the provision of contextual physics educational media that integrates local cultural heritage with technological innovation to ensure the successful implementation of the Merdeka Curriculum.

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