PILLAR OF PHYSICS EDUCATION
Vol. 19 (3), 2026, pp. 333–348
ISSN (Print) : 2337-9618
ISSN (Online) : 2684-8880

DESIGN OF AN E-MODULE BASED ON COGNITIVE CONFLICT, INTEGRATING *DEEP LEARNING* AND LOCAL WISDOM TO REMEDIATE STUDENTS' MISCONCEPTIONS ON SOUND WAVES

Meli Agusri[1] , Fatni Mufit[1*] , Hidayati[1] , Renol Afrizon[1]

[1] *Department of Physics, Universitas Negeri Padang, Jl. Prof. Dr. Hamka Air Tawar, Padang 25131, Indonesia*
Corresponding author. Email:fatni_mufit@fmipa.unp.ac.id

ABSTRACT

Misconceptions regarding sound waves are a common challenge in physics education, necessitating instructional materials that can help students improve their conceptual understanding. This study aims to describe the characteristics of a cognitive conflict-based e-module that integrates deep learning and local wisdom to remediate students' misconceptions about sound waves, as well as to assess the validity and practicality of the developed product. This study employed a research and development method using Plomp's development model, which includes the stages of preliminary research, prototype development, and evaluation. The e-module was developed using Canva and Google Sites by integrating the stages of cognitive conflict: activation of preconceptions and misconceptions, presentation of cognitive conflict, discovery of concepts and equations, and reflection. The principles of deep learning include mindful learning, meaningful learning, and joyful learning, while the local wisdom of Nagari Surian specifically the saluang, talempong, and rabab was used as the learning context. Product validation was conducted by three physics lecturers from Padang State University. A practicality test was carried out through one-on-one evaluations involving three students representing high, medium, and low academic ability levels, as well as assessments by teachers. The validation results showed that the e-module falls into the "highly valid" category with an average Aiken's V index of 0.94. The results of the one-on-one evaluations showed that the e-module falls into the "highly practical" category with an average percentage of 95.7% based on student assessments. Meanwhile, the teacher assessment results indicated a practicality percentage of 96.875%, also falling into the "highly practical" category. Overall, the research results indicate that the developed e-module meets the criteria for being highly valid and highly practical for use in physics instruction. This study was limited to testing the validity and practicality of the product; therefore, the effectiveness of the e-module in remediating students' misconceptions cannot yet be concluded and requires further testing.

Keywords: e-module; cognitive conflict; deep learning; local wisdom; misconceptions.

Pillar of Physics Education is licensed under a Creative Commons Attribution ShareAlike 4.0 International License.

I. INTRODUCTION

In the 21st century, physics education focuses not only on mastering formulas and memorization but also emphasizes a deep and meaningful understanding of concepts. Students are expected to understand concepts holistically and relate them to phenomena in everyday life. Conceptual understanding is crucial in physics education because physics concepts are interconnected and organized systematically [1]. Errors in understanding basic concepts can lead to misconceptions that impact the understanding of more advanced concepts [2]. Therefore, physics instruction must be designed so that students can build accurate scientific understanding from the very beginning. However, this goal has not yet been fully achieved because misconceptions remain a problem in physics education. A misconception is an understanding that does not align with scientific concepts but is believed to be true by students [3]. Misconceptions can arise from everyday experiences that are interpreted incorrectly, as well as from learning processes that do not take students' prior knowledge into account [4]. Students who already have incorrect prior conceptions tend to cling to their existing understanding, making it difficult to correct these

misconceptions through conventional instruction. This situation highlights the need for instruction that not only conveys information but also helps students identify and correct their misconceptions [3].

One topic in physics that frequently leads to misconceptions is sound waves. This topic is abstract in nature because it involves wave propagation through a medium, the properties of sound, and the phenomena of resonance and reflection [5]. Some of the misconceptions identified include the belief that the speed of sound is influenced by the frequency of the sound source, that sound can propagate without a medium, and errors in understanding wave superposition and reflection [6]. In addition, students also have difficulty understanding the conditions for resonance in air columns and strings. These various misconceptions indicate the need for instructional materials that can connect abstract concepts with concrete phenomena so that students can develop an accurate scientific understanding [7].

One alternative to address these issues is to develop digital instructional materials in the form of cognitive conflict-based e-modules. E-modules can serve as learning resources that present material through a combination of text, images, and various multimedia elements, thereby capturing students' attention and supporting the learning process [8]. The integration of the cognitive conflict-based learning model (PbKK) enables students to compare their initial understandings with phenomena or scientific evidence that contradicts their concepts [9]. Cognitive conflict-based learning consists of four stages: activation of preconceptions and misconceptions, presentation of cognitive conflict, discovery of concepts and similarities, and reflection [9]. Through these stages, students are guided to identify their initial understanding, confront conceptual conflicts, discover scientific concepts, and reevaluate their understanding.

The development of cognitive conflict-based instructional materials has been undertaken in several previous studies. Study [10] conducted a needs analysis for cognitive conflict-based instructional materials integrated with augmented reality on the topic of sound waves. The results indicated the need to develop technology-based instructional materials to support the identification and remediation of misconceptions. Study [11] developed cognitive conflict-based instructional materials that integrated a virtual laboratory into optics content and achieved validation results in the "highly valid" category. Meanwhile, study [12] developed print-based physics modules grounded in cognitive conflict using a 4D model, which was deemed highly feasible based on expert and practitioner evaluations as well as limited pilot testing. These studies have contributed to the development of cognitive conflict-based instructional materials, both in digital and print formats. However, these developments have not yet specifically integrated cognitive conflict, the deep learning approach, and local wisdom into a single e-module on sound waves.

The development of e-modules must also consider learning approaches that support student engagement in building conceptual understanding. One relevant approach is deep learning. This approach emphasizes three main principles: mindful learning, meaningful learning, and joyful learning [13]. Mindful learning helps students recognize their prior knowledge and understand their learning process. Meaningful learning connects new knowledge with experiences and phenomena in daily life, while joyful learning creates an engaging learning environment that encourages student engagement. The integration of the deep learning approach with cognitive conflict is expected to support the process of conceptual change through activities such as identifying misconceptions, addressing conflicts, discovering concepts, and engaging in reflection [14].

In addition to the instructional approach, the use of contexts relevant to students' lives is also necessary to make learning more meaningful. Local wisdom can serve as a learning resource that connects scientific knowledge with the culture and experiences of the local community [15], [16]. Research [17] indicates that local wisdom in Indonesia has the potential to be utilized in physics instruction because it encompasses various concepts, including vibrations and waves. In the context of Minangkabau society, there is the philosophy of "Alam Takambang Jadi Guru," which teaches that the environment and all phenomena within it can serve as sources of learning [18]. Therefore, this study utilizes the local wisdom of Nagari Surian in the form of traditional musical instruments the saluang, talempong, and rabab as a learning context for sound waves.

The selection of these three musical instruments is based on their close connection to the cultural life of the Minangkabau people as well as their distinct physical characteristics in producing sound. The saluang is a wind instrument that produces sound through the vibration of a column of air, making it relevant to the concepts of frequency and resonance. The talempong is a metal percussion instrument that produces sound through the vibration of the instrument's body when struck, making it suitable for discussing frequency, amplitude, and the sound's " " [19]. Meanwhile, the rabab is a stringed instrument that produces sound through the vibration of its strings and the resonance of the instrument's body. The differences in the sound-production mechanisms of these three musical instruments provide students with the opportunity to observe and compare sound phenomena based on physics concepts. The use of traditional Minangkabau musical instruments as a learning context is also

consistent with a study [20] that examined the physical parameters of Minangkabau wind instruments as a meaningful learning context. Thus, local wisdom serves not only as a cultural element in the e-module but also as a context for constructing an understanding of the concept of sound waves.

Based on previous research, the development of instructional materials based on cognitive conflict has been conducted across various subjects and media [10]–[12]. Study [21] also developed an interactive e-module based on cognitive conflict and a deep learning approach for light waves, which was rated as highly valid and highly practical. However, that study focused on light waves and did not integrate local wisdom as a learning context. On the other hand, research on local wisdom in physics education has demonstrated its potential as a contextual learning resource [17], but it has not yet been specifically integrated with the stages of cognitive conflict and the principles of deep learning in the development of e-modules on sound waves. Thus, there is a research gap in the form of the lack of integration of these three elements into a single digital learning product on the topic of sound waves. The novelty of this study lies in the development of a Google Sites-based e-module that integrates the four stages of cognitive conflict, the three principles of deep learning, and the local wisdom of Nagari Surian specifically the saluang, talempong, and rabab as a learning context to support the remediation of students' misconceptions.

The e-module was developed using the Plomp model, which includes the stages of preliminary research, prototype development, and evaluation [22]. This model enables systematic product development based on needs analysis, design, and product evaluation and refinement. Product evaluation was conducted through expert validation and practicality testing to assess the appropriateness of the content, instructional design, visual presentation, and ease of use of the e-module. Both aspects are necessary to ensure that the developed product meets quality criteria before further testing is conducted.

Based on the above description, this study aims to describe the characteristics, determine the validity, and assess the practicality of a cognitive conflict-based e-module that integrates the deep learning approach and local wisdom to remediate students' misconceptions regarding sound waves. This study focuses on product development as well as testing validity and practicality using the Plomp model. Thus, the research results are expected to provide an alternative contextual digital teaching material that supports efforts to remediate students' misconceptions in physics learning.

II. METHOD

This study is a research and development (R&D) project, specifically educational design research, aimed at designing, developing, and validating a product as a solution to a complex research problem [22]. The development model used is the Plomp and Nieveen (2013) model, which consists of three phases: preliminary research, development or prototyping, and assessment. This study is limited to the one-to-one evaluation phase. This limitation was imposed because the research objective is to produce a valid and practical e-module, which can be assessed through expert evaluation and initial practical testing. Testing the effectiveness of the e-module and its ability to remediate misconceptions requires a further evaluation phase with a larger number of participants. Therefore, the small-group testing and field testing phases were not conducted in this study.

A preliminary research phase was conducted to identify learning problems related to sound waves as the basis for developing the e-module. This phase included a needs and context analysis as well as a literature review. The needs analysis was conducted through interviews with physics teachers to gather information regarding instructional practices, the teaching materials used, and the challenges students face in understanding the concept of sound waves. Additionally, an analysis of the suitability of the textbooks used in schools was conducted based on the four criteria of suitability according to the National Education Standards Agency (BSNP) 2006. Student misconceptions were identified using a four-tier diagnostic test *(5TDT-HoTS)* adapted from Firdausi [23] and administered to 22 students at SMAN 1 Pantai Cermin. The instrument consists of four levels: accuracy of answers, level of confidence in answers, accuracy of reasoning, and level of confidence in reasoning. The 5TDT-HoTS instrument developed by Firdausi has undergone validity testing by four experts and reliability testing. The test results showed an overall validity value of 0.80, classified as "highly valid," and a Cronbach's Alpha reliability value of 0.953, indicating "highly reliable" reliability [23]. The results of the " " test were analyzed based on a combination of these four components and then grouped into three categories conceptual understanding, misconceptions, and lack of conceptual understanding to determine students' prior understanding of sound wave material. A literature review was conducted based on the issues identified during the needs analysis phase to identify the material sources of misconceptions, the types of misconceptions that occurred, and the learning problems that caused them. The results of this analysis served as the basis for determining the requirements and characteristics of the e-module being developed.

The development stage aimed to design a product in the form of a cognitive conflict-based e-module integrated with deep learning and local wisdom to remediate students' misconceptions regarding sound waves.

The product was then evaluated through formative assessment based on the Tessmer diagram. The e-module was designed using Canva Pro and published via Google Sites to make it digitally accessible. The formative evaluation consisted of three steps: self-evaluation, expert review, and one-on-one evaluation. The self-evaluation was conducted by the researcher to check the completeness of components, the appropriateness of content and presentation, and potential errors in the initial product. The expert review was conducted by three physics lecturers from the Faculty of Mathematics and Natural Sciences at Padang State University, who acted as validators to assess the validity of the e-module using a validation instrument. The assessment results and recommendations from the validators were used as the basis for revising the product. Subsequently, a one-on-one evaluation was conducted to assess the practicality of the e-module, involving three students from SMAN 1 Pantai Cermin representing high, medium, and low academic ability levels, as well as two physics teachers from the same school. Student selection was based on physics grades and teacher recommendations. Research data at this stage included quantitative data in the form of self-evaluation scores, validity, and the practicality of the e-module, while qualitative data was obtained from the results of the needs analysis as well as suggestions and feedback from the validators.

The assessment phase of this study was limited to the one-to-one evaluation stage. The assessment focused on obtaining information regarding the initial validity and practicality of the e-module through evaluations by experts, students, and teachers. The small-group testing and field testing stages were not conducted because this study focused on product development and initial testing, rather than on testing the effectiveness of the e-module in remediating students' misconceptions. The self-evaluation scores were analyzed by the researcher to refine the e-module before submitting it to validators using a percentage-based technique formulated as follows.

$$Score = \frac{\text{Score}}{\text{Maximum score}} \times 100 \qquad (1)$$

Product validity was assessed using an instrument completed by three physics lecturers from the Faculty of Mathematics and Natural Sciences at Padang State University, who served as validators. The instrument was designed using a Likert scale based on [24], which is a scale used to measure the attitudes, opinions, and perceptions of an individual or group toward a particular object. This scale consists of five response options: strongly disagree, disagree, undecided, agree, and strongly agree. The validity results were then analyzed using Aiken's V validity index, which is formulated as follows.

$$V = \frac{\sum S}{n(c-1)} \qquad s = r - l_0 \qquad (2)$$

V = validity index
$\sum S$ = the sum of all s values from all validators
n = number of validators
l_0 = the lowest validity score
c = the highest validity score
r = the score given by the validator

The resulting Aiken's V index is then interpreted based on the validity criteria used in the study.

Table 1. Validity criteria based on Aiken's V index

Interval	Category
$\leq 0{,}4$	Invalid
$0{,}4 \leq V \leq 0{,}8$	Valid
$0{,}8 \leq V \leq 1$	Highly Valid

(Source: [25])

These criteria were used to determine the validity level of the e-module and served as the basis for product improvements based on suggestions and feedback from three expert validators. After revisions were made, the e-module was then implemented in a one-to-one evaluation phase involving three students representing high, medium, and low academic ability levels, as well as two physics teachers at the school.

The practicality assessment was conducted by having students and two physics teachers at SMAN 1 Pantai Cermin complete an evaluation instrument. The practicality questionnaire covered four assessment aspects: ease of use, appeal, efficiency, and the benefits of the e-module. The practicality data were analyzed by calculating the percentage of the score obtained relative to the maximum score using the following formula.

$$\text{Score} = \frac{\text{Weighted score}}{\text{Maximum weight}} \times 100 \quad (3)$$

The e-module's practicality level was determined based on the percentage of the assessment results on the practicality instrument. This percentage was then interpreted into five categories: very practical, practical, fairly practical, less practical, and impractical [26], as presented in Table 2.

Table 2. E-Module Practicality Categories

Score	Category
81%–100%	Very Practical
61%–80%	Practical
41%–60%	Fairly Practical
21%–40%	Not Very Practical
0–20%	Not Practical

(Source: [26])

This categorization aims to determine the level of practicality of the e-modules based on student and teacher evaluations, particularly in terms of ease of use, appeal, efficiency, and benefits for learning.

III. RESULTS AND DISCUSSION

RESULTS

The following presents the research results from the preliminary research phase and the development or prototyping phase. The research results include a needs and context analysis, a literature review, the design of the e-module prototype, the results of self-evaluation, the results of expert review, and the results of practicality testing through one-to-one evaluation. Additionally, a discussion linking the findings from the preliminary research phase to the product development results is presented.

Preliminary Research Phase

Needs and Context Analysis

A needs and context analysis was conducted to identify learning problems related to sound waves, which served as the basis for the development of the e-module. A concept comprehension test was administered to 22 11th-grade students in Class F at SMA Negeri 1 Pantai Cermin using a four-tier diagnostic instrument adapted from [23]. The test results are presented in Table 3.

Table 3. Percentage of Misconceptions by Content Indicator

Category	Average Percentage (%)
Conceptual Understanding	6.4
Lack of Conceptual Understanding	28.4
Misconceptions	65.2

The diagnostic test results in Table 3 show that the majority of students fall into the misconception category (65.2%), followed by the "lack of conceptual understanding" category (28.4%), while only 6.4% of students demonstrate conceptual understanding. These figures confirm that misconceptions are the primary issue in the teaching of sound waves. The high prevalence of misconceptions means that students hold ideas that contradict scientific concepts, while the proportion of students who do not understand the concept indicates that there are still students who lack the foundational understanding needed to explain sound phenomena. Therefore, the identified problems cannot be adequately addressed simply by repeating explanations or adding more practice problems; rather, instruction is needed that encourages students to recognize and re-examine their initial ideas.

The small percentage of students who understand the concept compared to the other two categories was also a consideration in designing the e-module. The product needs to provide space for students to express their initial hypotheses, test them through relevant phenomena or evidence, and then understand the correct scientific explanation. It should be emphasized that the diagnostic test in this study was used to identify development needs, not to prove the success of remediation. The results served as a reference for developing content, prompt questions, cognitive conflict activities, and reflection sections in the e-module.

In addition to this general overview, misconceptions were also analyzed for each indicator related to sound waves. This step is important because the level of misconceptions varies from concept to concept. Thus, it is possible to identify which concepts require greater emphasis in the presentation of material and learning activities.

Table 4. Percentage of Student Concept Understanding for Each Indicator of Sound Wave Material

No.	Question Indicator	Concept Understanding (%)	Misconceptions (%)	Lack of Conceptual Understanding (%)
1.	Analyzing the characteristics of sound waves	6.8	70.5	22.7
2.	Comparing differences in pitch and sound intensity	13.6	72.7	13.6
3.	Analyzing the propagation of sound in solids	0	86.4	13.6
4.	Identifying the correct statement regarding the Doppler effect	0	81.8	18.2
5.	Formulate the concept of the Doppler effect based on the events presented in the question	4.5	72.7	22.7
6.	Calculate the frequency of the sound received by the listener	4.5	75.0	20.5
7.	Understanding the concept of sound waves and calculating the frequency of sound waves	9.1	45.5	45.5
8.	Formulating a hypothesis based on the concept of resonance	4.5	63.6	31.8
9.	Calculate the height of the air column when resonance occurs	18.2	50.0	31.8
10.	Comparing the sound intensity levels received by the listener	0	54.5	45.5
11.	Calculating sound intensity	18.2	59.1	22.7
12.	Comparing Sound Intensity Levels at Two Different Points	0	63.6	36.4
13.	Comparing the lengths of open and closed organ pipes	0	50.0	50.0
14.	Analyzing the pitch frequency of a closed organ pipe	0	59.1	40.9
15.	Determining the tension in the strings	4.5	54.5	40.9

Based on Table 4, the highest rate of misconceptions was found in the indicator for sound propagation in solids (86.4%). Next, the indicator for correct statements about the Doppler effect reached 81.8%, the indicator for calculating the frequency received by the listener was 75%, and the indicators for comparing pitch with sound intensity and formulating the concept of the Doppler effect were each 72.7%. In the "conceptual understanding" category, there were six indicators with a 0% percentage: sound propagation in solids, statements regarding the Doppler effect, comparison of sound intensity, comparison of sound intensity levels, and two indicators related to organ pipes. The highest number of students who did not understand the concepts was found in the indicator comparing the lengths of open and closed organ pipes (50%). This finding indicates that students have difficulty understanding the relationship between the sound source, the medium of propagation, frequency, and the relative motion of the source to the listener. These concepts are interconnected, so a misunderstanding of one concept can affect the others. For example, students need to understand that the speed of sound is influenced by the properties of the medium, while the frequency perceived by the listener depends on the relative speed of the source and the listener, not on changes in the frequency emitted by the source.

The results of this needs analysis serve as the foundation for guiding the development of the e-module. The content and activities are designed so that students can review their initial ideas, encounter situations that challenge those ideas, discover scientific explanations, and reflect on their understanding. In this way, the needs analysis provides an empirical basis for the characteristics of the developed product, particularly in the selection of cognitive conflict models and the contextual presentation of sound wave material.

Literature Review

A literature review was conducted to establish a theoretical foundation for determining solutions to students' conceptual understanding issues and misconceptions regarding sound wave material. The planned solution is the development of a cognitive conflict-based e-module integrated with a deep learning approach and local wisdom. An e-module is a digital instructional resource systematically organized to help students understand the material through text, images, phenomena, activities, and assessments. [27] indicates that e-learning modules have the potential to help remediate misconceptions in physics learning. Thus, e-modules can be designed as self-directed learning tools that facilitate students' understanding of sound wave concepts.

The Cognitive Conflict-Based Learning Model (PbKK) is used to help students recognize and correct discrepancies between their prior understanding and scientific concepts. This model consists of four stages: activation of preconceptions and misconceptions, presentation of cognitive conflicts, discovery of concepts and equations, and reflection [4]. A meta-analysis [3] supports the use of cognitive conflict in physics instruction. Through these stages, students are expected to be able to identify misconceptions, reexamine their prior understanding, and develop a more accurate conceptual understanding.

The deep learning approach is integrated through three principles: mindful, meaningful, and joyful [28]. The mindful principle helps students recognize their prior understanding; the meaningful principle connects concepts to real-world experiences; and the joyful principle encourages active engagement in learning. These three principles support the process of cognitive conflict so that students do not merely memorize formulas but also understand concepts and reflect on changes in their understanding.

The local traditions of Nagari Surian such as the saluang, talempong, and rabab are used as a learning context to connect the concept of sound waves with phenomena in everyday life. Traditional musical instruments can be used to observe frequency, amplitude, and sound characteristics. A study [29] demonstrates the potential for using traditional musical instruments in teaching sound waves. Based on this study, an e-module on the Google Sites platform was designed by integrating PbKK, deep learning principles, and local wisdom to support students' conceptual understanding and address their misconceptions. This design aligns with the principles of Educational Design Research, which prioritizes needs analysis and theoretical review as the foundation for product development [22].

Development or Prototyping Phase

Product Design

The design phase aims to develop instructional materials in the form of e-modules designed to address misconceptions and improve students' conceptual understanding of sound waves. The e-module was designed using Canva to organize the layout and learning content, then integrated into the Google Sites platform to make it digitally accessible. The development of the e-module followed the module structure outlined by the Ministry of National Education [30], which includes the title, learning instructions, competencies to be achieved, supporting information, assignments, activity steps, and assessment. All these components are integrated with four stages of cognitive conflict-based learning namely, the activation of preconceptions and misconceptions, the presentation of cognitive conflicts, the discovery of concepts and equations, and reflection which are combined with the three principles of the deep learning approach: mindful, meaningful, and joyful. In addition, the e-module integrates the local wisdom of Nagari Surian such as the saluang, talempong, and rabab as a learning context to connect the concept of sound waves with phenomena in everyday life.



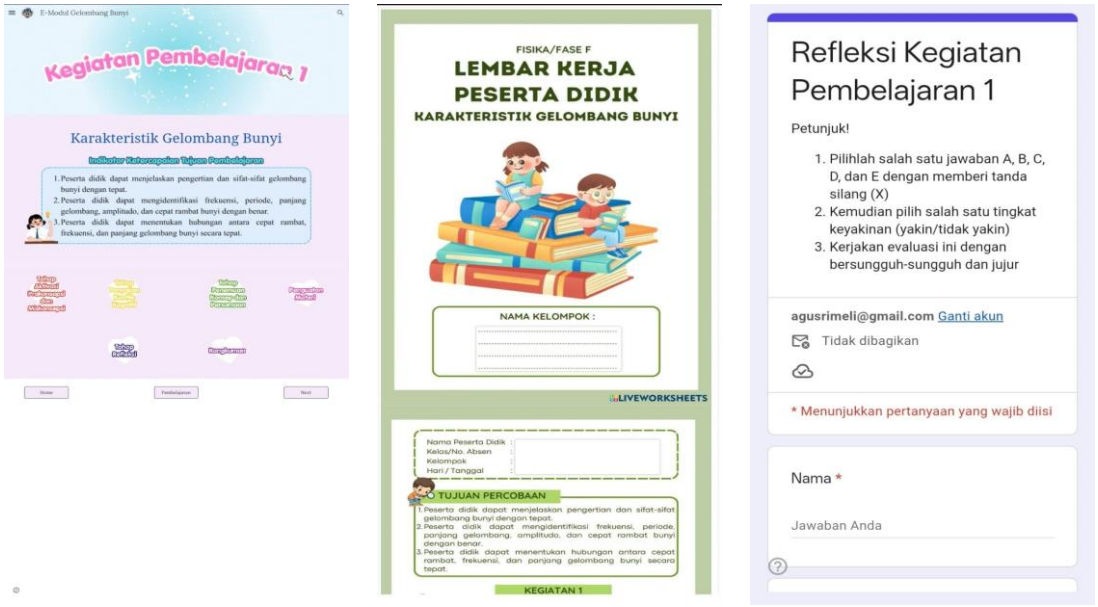
(a)



(b)

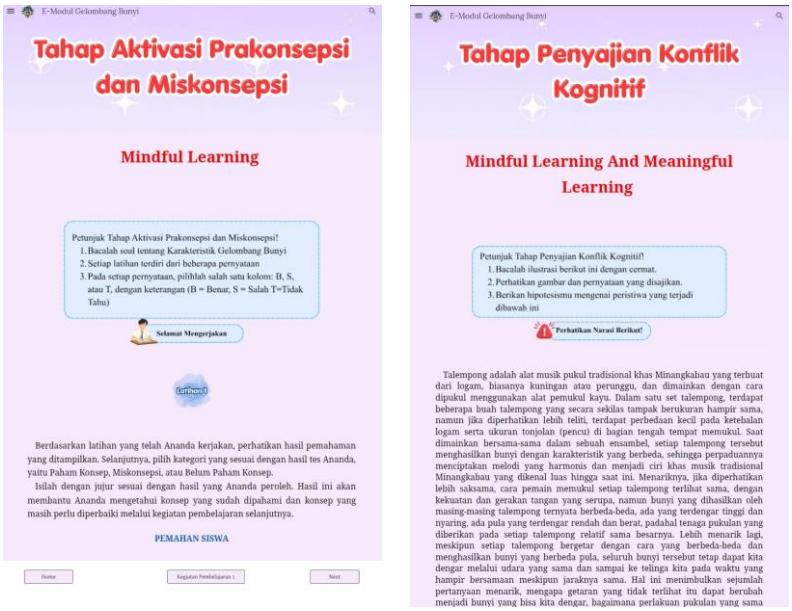


(c)



(d) (e) (f)

Fig. 1. Sections of the E-Module: (a) Cover and main menu, (b) Introduction, (c) Learning, (d) Learning Activities, (e) Worksheets, and (f) Reflection on learning activities



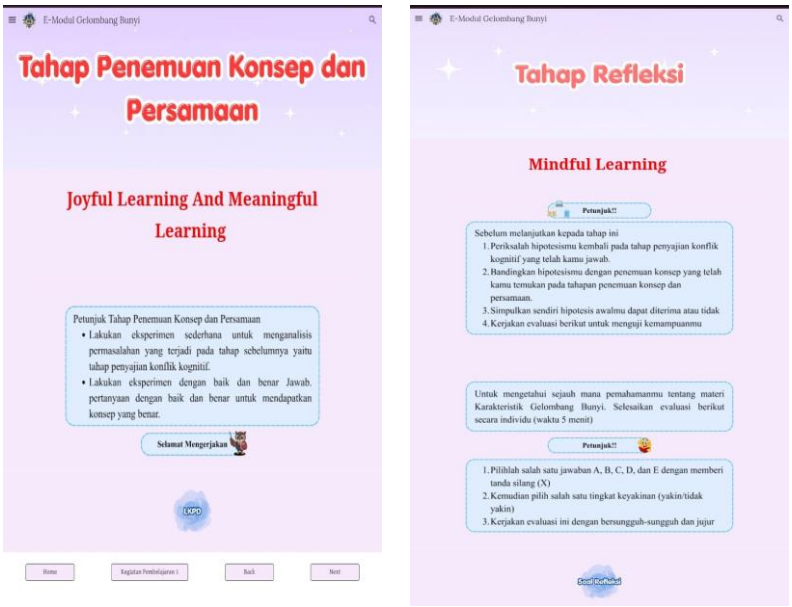
(a) (b)

Fig. 2. E-Module at: (a) the Activation of Preconceptions and Misconceptions stage and (b) the Presentation of Cognitive Conflict stage

The first phase, the activation of preconceptions and misconceptions, aims to identify students' prior knowledge before learning begins as a basis for determining appropriate instructional strategies. In this stage, students are presented with statements related to the basic concepts of sound waves through a quiz link integrated into Google Sites. This stage applies the principle of mindful learning by encouraging students to become aware of, recognize, and identify their prior understanding before learning new concepts.

The second syntax, the presentation of cognitive conflict, aims to expose students to everyday phenomena that contradict their prior understanding. These phenomena are designed to create a conflict between students' initial conceptions and scientific explanations, thereby fostering conceptual change. At this stage, students are asked to formulate tentative hypotheses based on the presented phenomena. The principle of meaningful learning is applied by connecting the phenomenon of sound waves to everyday experiences and the local wisdom of Nagari

Surian, such as the saluang, talempong, and rabab, while the principle of meaningful learning is also realized through opportunities for students to relate their prior knowledge to the phenomenon being studied.



(a) (b)

Fig. 3. E-Module at: (a) the Concept and Equation Discovery Stage and (b) the Reflection Stage

The third syntax, namely the discovery of concepts and equations, aims to help students build an understanding of sound wave concepts through laboratory activities. In this activity, students make observations, collect data, and analyze the results of the laboratory experiment to discover concepts and relationships between physical quantities in sound waves. The principle of joyful learning is applied through laboratory activities that actively engage students and provide an engaging learning experience, while the principle of meaningful learning is realized through the process of discovering concepts based on observations and analyses related to real-world phenomena.

The fourth phase, reflection, aims to assess changes in students' conceptual understanding after completing the previous three learning phases. This activity involves reviewing initial hypotheses and administering an assessment using a four-tier multiple-choice diagnostic instrument. This instrument is used to identify students' categories of understanding: conceptual understanding, lack of conceptual understanding, or misconceptions. This stage applies the principle of meaningful learning by encouraging students to reflect on changes in their understanding, connect the concepts they have learned with their prior knowledge, and build a more accurate understanding of the phenomenon of sound waves in everyday life.

Self-Evaluation

A self-evaluation was conducted to verify the alignment of the e-module prototype with the development plan before proceeding to the expert validation stage. The evaluation covered six aspects: the e-module itself, its components, its design, cognitive conflict syntax, the integration of deep learning, and the integration of local wisdom. This review aims to identify shortcomings in the structure, presentation, and application of the learning approach so that they can be corrected before the product is assessed by validators.

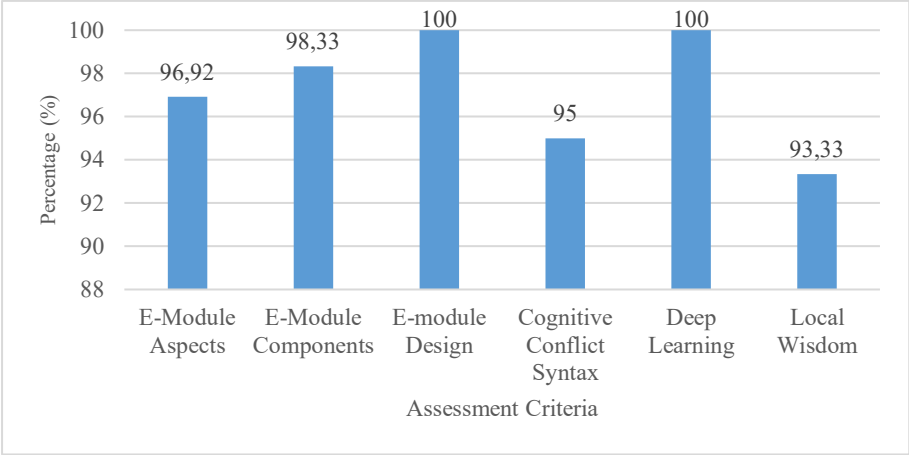


Fig. 4. Self-Evaluation Results

Based on Figure 4, the self-evaluation percentages are as follows: e-module aspect 96.92%, e-module components 98.33%, e-module design 100%, cognitive conflict syntax 95%, deep learning integration 100%, and integration of local wisdom 93.33%. The highest percentages were found in the e-module design and deep learning integration aspects, while the lowest percentage was found in the integration of local wisdom. These results indicate that the prototype meets most of the established criteria, although the integration of local wisdom still requires attention during product refinement. However, the self-evaluation results cannot be treated as a substitute for expert validation because the assessment was conducted by the developers on their own product. Therefore, self-evaluation serves as a preliminary review, while the accuracy of the content, the appropriateness of the instructional design, and the quality of presentation need to be further assessed through expert validation.

Expert Review

The e-module was validated by three physics lecturers from the Faculty of Mathematics and Natural Sciences, Padang State University, using an assessment instrument consisting of four components. The validation data were analyzed using Aiken's V index. A summary of the validation results for all components is presented in Figure 5.

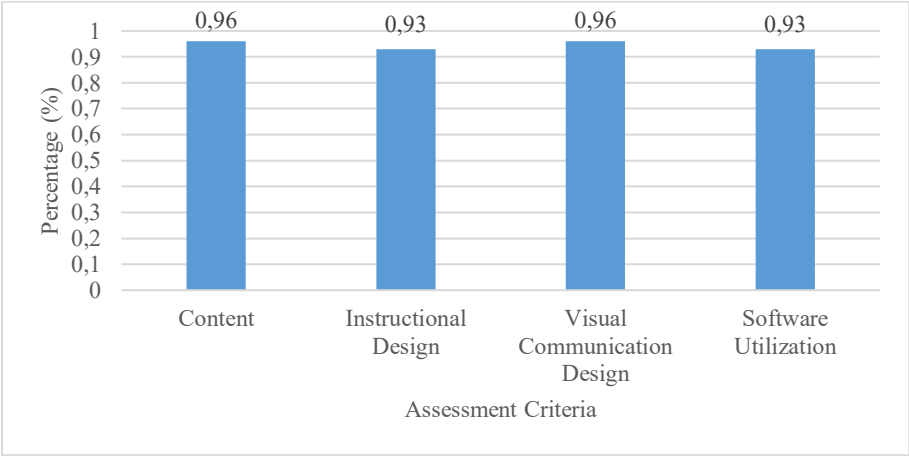


Fig. 5. Expert Validation Results

Figure 5 shows that the validity scores of the e-module range from 0.93 to 0.96, placing it in the "highly valid" category. These results indicate that the developed e-module meets the validity criteria based on the experts' assessment. Based on the graph, all four assessment aspects showed high and relatively consistent validity scores. The content substance and visual communication aspects received the highest score of 0.96. These results indicate that the presented material is appropriate, accurate, and relevant to the learning objectives, and that the e-module's visual design is well-structured and easy to understand. Meanwhile, the instructional design and software utilization aspects each received a score of 0.93. This indicates that the instructional content was organized systematically and that the software used effectively supported the development of the e-module.

Overall, all four aspects received high validity scores, with a difference of only 0.03 between the highest and lowest scores. Thus, the developed e-module falls into the "highly valid" category and is suitable for proceeding to the practicality evaluation stage.

Product revisions were made based on feedback from the validators to improve the quality of the developed e-modules. Revisions included corrections to the text on the cover, changes to the concept map layout, improvements to the formatting of source links and formulas, and adjustments to the instructions for each exercise. Additionally, images in Worksheet 2 and the experiment in Worksheet 3 were replaced to better align with the material. In terms of presentation, the text layout was adjusted for greater neatness, more contrasting text colors were selected, and explanations regarding musical instruments were refined. Furthermore, the learning pages were restructured using subtopics as headings; a column for student understanding was added during the activation stage addressing preconceptions and misconceptions; and the exercises for that stage were combined into a single set. The display of YouTube videos was also improved to allow for direct viewing; validator information was updated; and the objectives of the experiments were aligned with the IKTP.

Practicality (One-to-One Evaluation)

A practicality assessment was conducted with three students from SMAN 1 Pantai Cermin representing high, medium, and low ability levels. The assessment used an evaluation instrument consisting of four aspects: ease of use, appeal, efficiency, and benefits. The three students completed the evaluation instrument independently while being supervised by the researcher to ensure all items were filled out. Comments and suggestions from the students were also collected but have not been analyzed further in this article. This feedback will be used as input for revisions should development proceed to the small-group testing or effectiveness testing phases. The results of this evaluation are presented as preliminary evidence regarding the practicality of the e-module, taking into account the still very limited number of respondents.

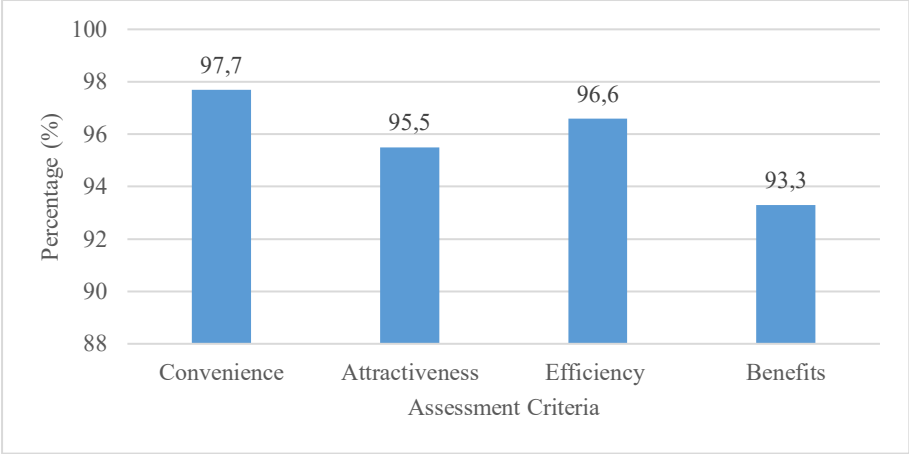


Fig. 6. Student Practicality Results

Based on Figure 6, which shows the students' practicality results, scores were obtained for four assessment aspects: ease of use (97.7%), appeal (95.5%), efficiency (96.6%), and usefulness (93.3%). The ease of use aspect received the highest score, indicating that the e-module is easy for students to use. The efficiency aspect received a score of 96.6%, indicating that the e-module is considered efficient in supporting the learning process. Furthermore, the appeal aspect received a score of 95.5%, indicating that the e-module is highly appealing to students. Meanwhile, the benefit aspect received a score of 93.3%, which was the lowest compared to the other aspects but still reflected a positive assessment of the e-module's benefits in supporting the learning process.

Overall, these results show that the developed e-module has a very high level of practicality based on students' evaluations. Thus, it can be concluded that the product's practicality from the students' perspective falls into the "very practical" category. This means the product can be used to optimize the physics learning process in schools and support students in independent learning, whether with or without a teacher present. However, these results represent preliminary evidence of practicality; therefore, further testing with a larger number of students is needed to obtain a more comprehensive picture of its practicality.

Practicality of the E-Module as Assessed by Teachers

The practicality of the e-module was assessed by two physics teachers at SMAN 1 Pantai Cermin. The teacher-led practicality assessment aimed to evaluate the extent to which the e-module based on cognitive conflict and integrating deep learning and local wisdom to address students' misconceptions regarding sound waves can be utilized in the learning process from an educator's perspective. The practical testing phase began by providing the teachers with access to the e-module, followed by a briefing on how to use it and an explanation of its components. The teachers were asked to study the material, instructions, and learning activities presented.

Afterward, they were given instructions on how to complete the practical testing evaluation instrument and asked to fill it out based on their experience after reviewing the e-module.

Through this practical assessment, teachers' responses to the e-module were gathered based on four evaluation aspects: ease of use, appeal, efficiency, and benefits. The data from the teachers' practical assessment are presented in graph form in Figure 7.

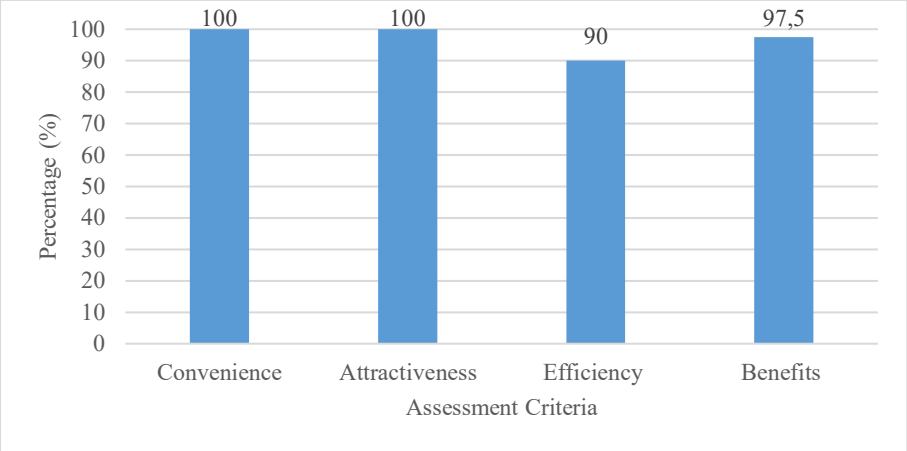


Fig. 7. Results of the Teacher Practicality Assessment

Based on the graph in Figure 7, it is evident that the e-module which integrates deep learning and local wisdom based on cognitive conflict received very high scores from teachers across every evaluation aspect. The ease-of-use and appeal aspects each scored 100%, the efficiency aspect scored 90%, and the benefit aspect scored 97.5%. Overall, the average practicality score of the developed e-module was 96.875%, placing it in the "highly practical" category. This indicates that the e-module can be effectively utilized in the learning process.

DISCUSSION

The results of the preliminary study indicate that students' understanding of sound wave material remains an issue that requires attention, particularly in distinguishing scientific concepts from ideas formed based on everyday experiences. This issue is related to the characteristics of sound wave material, which require an understanding of the relationships between concepts and physical quantities. The findings of [7] on students' misconceptions regarding mechanical waves, as well as those of [6] on misconceptions regarding the concepts of vibration and waves, indicate that conceptual understanding issues are also present in wave-related material in general. These findings are supported by [31], who, through a literature review, identified misconceptions in several subtopics of sound waves, particularly sound propagation, the relationship between speed of sound, frequency, and wavelength, sound intensity, and the Doppler effect. These research results are consistent with the findings of a preliminary study indicating that students' difficulties are spread across several indicators of sound wave material. Thus, identifying students' prior understanding is a crucial step in determining the needs and characteristics of the instructional materials to be developed. This situation served as the basis for the development of a cognitive conflict-based e-module designed to help students express their prior understanding, revisit their ideas, and build understanding based on scientific concepts.

Analysis of each content indicator revealed that students' difficulties are not only related to the characteristics of sound waves but also encompass sound propagation, the Doppler effect, sound intensity, resonance, and organ pipes. These findings highlight the need for instructional materials that link conceptual understanding with the application of physics equations. The use of a four-tier diagnostic test in the preliminary study provided insight into students' understanding through their answers, justifications, and levels of confidence in both. This aligns with the research by [5], who developed a diagnostic test to identify high school students' conceptual understanding of sound waves. Meanwhile [20] developed a five-tier diagnostic test oriented toward Higher-Order Thinking Skills (HOTS) on the same subject matter. Both studies highlight the importance of diagnostic instruments in identifying conceptual understanding issues in a more targeted manner. The results of Nugraha's [32] study also indicate that the use of a four-tier diagnostic test can reveal categories of student understanding regarding mechanical waves and light waves. Although they covered different subject matter, these studies reinforce the relevance of using tiered diagnostic tests to identify students' understanding and misconceptions. Therefore, the results of the preliminary study were used as the basis for determining the scope of the subject matter, contextual phenomena, learning activities, and reflective questions included in the e-module.

The e-module that was developed integrates learning instructions, content, contextual phenomena, learning activities, hands-on activities, and reflections into a single digital learning resource. The content and visual of the e-module were designed using Canva and then published via Google Sites so that students can access it through digital devices. The product's structure aligns with the instructional material development guidelines from the Directorate of Senior High School Development [30], which emphasize the completeness of components and the systematic presentation of instructional materials. The product's development also follows the principles of Educational Design Research proposed by [22], namely that development is based on needs analysis and theoretical foundations, followed by gradual evaluation to gather feedback for product refinement. These characteristics align with the research by [33], who developed a cognitive conflict-based e-module on measurement material involving the stages of preconception activation, presentation of cognitive conflict, concept discovery, and reflection. The similarity between the two studies lies in the use of cognitive conflict stages as the structure of learning activities. The differences lie in the material developed and the integration of learning approaches. This study specifically developed an e-module on sound waves by integrating deep learning principles and local wisdom. Thus, the product's contribution lies in the combination of digital instructional materials with learning activities tailored to students' comprehension challenges regarding sound waves.

The application of the Cognitive Conflict-Based Learning (PbKK) model is one of the key characteristics of the developed e-module. Learning activities are organized into four stages: activation of preconceptions and misconceptions, presentation of cognitive conflicts, discovery of concepts and equations, and reflection. In the first stage, students are guided to express their initial understanding of sound wave phenomena. The second stage presents phenomena that can create a conflict between students' initial ideas and scientific explanations. Next, the third stage guides students to discover concepts and equations through learning activities and laboratory experiments, while the fourth stage provides students with an opportunity to review their understanding. This design is based on the CBLC model proposed by [4]. Its suitability is also supported by the results of a meta-analysis by [3], which showed that cognitive conflict-based learning has a positive effect on conceptual understanding and the management of misconceptions in physics learning. Research by [33] also showed that the stages of cognitive conflict can be integrated into the design of e-modules for different physics topics. These findings indicate that the cognitive conflict model can serve as a foundation for developing digital instructional materials. However, this research is still in the early stages of development and evaluation. Therefore, the application of the cognitive conflict stages in the e-module demonstrates the alignment of the design with the theoretical framework, not evidence that students' misconceptions have changed.

The integration of the deep learning approach and local wisdom further strengthens the characteristics of the e-modules. The principle of mindfulness is applied through activities that identify students' prior understanding; the principle of meaningfulness is realized by linking concepts to everyday phenomena; while the principle of enjoyment is applied through laboratory activities that engage students in observing and analyzing phenomena. This design is based on [13], who discuss the deep learning approach through conscious, meaningful, and enjoyable learning experiences. These three principles are integrated with the local wisdom of Nagari Surian namely, the saluang, talempong, and rabab as the learning context for sound waves. The use of traditional musical instruments provides a context closely tied to students' lives and culture for learning the concepts of vibration, frequency, amplitude, and sound characteristics. The integration of cultural context into learning is also in line with [15], who discusses the importance of local wisdom in the learning process. Additionally, Sriwahyuni [34] examines physics concepts in the creation of the traditional Tennong-Tennong musical instrument, while Louven [35] discusses the characteristics of the stone talempong in Talang Anau, West Sumatra. These studies demonstrate that traditional musical instruments possess physical aspects that can be linked to learning. Nevertheless, the use of the saluang, talempong, and rabab in this e-module represents a form of contextualizing the material based on the local cultural environment. This integration is expected to provide a learning experience more closely aligned with students' daily lives; however, its contribution to changes in conceptual understanding still requires further testing.

Expert validation results indicate that the e-module received valid ratings in the areas of content substance, instructional design, visual communication, and software utilization. These results indicate that the product has met the evaluation criteria based on the validation instrument used. The content aspect relates to the appropriateness of sound wave concepts and the accuracy of material presentation, while the instructional design aspect covers the appropriateness of cognitive conflict stages, the integration of deep learning principles, and the alignment of activities with learning objectives. The aspects of visual communication and software utilization relate to readability, layout, navigation, and the ease of accessing the product via Google Sites. The evaluation by expert lecturers provided input from the perspectives of science, learning, and media, ensuring that product refinement is not limited to visual appearance alone. Validity analysis used Aiken's V index in accordance with the use of this coefficient to measure content validity based on expert evaluation. These results align with the research by [11], who developed cognitive conflict-based instructional materials on optics and conducted a validity assessment of the developed product. Research by [33] also showed that e-modules based on cognitive conflict can receive valid ratings from experts. The similarity of these results indicates that expert validation is a crucial

step in ensuring the appropriateness of both the content and design of instructional materials before their further use. However, the validation results in this study only indicate the feasibility of the product based on the assessed aspects and cannot yet serve as a basis for concluding the effectiveness of the e-module in enhancing conceptual understanding or remediating students' misconceptions.

The results of the practicality evaluation from the students' perspective indicate that the e-modules were rated as easy to use, engaging, efficient, and beneficial in supporting learning activities. The ease-of-use aspect relates to students' ability to follow learning instructions, access materials, and utilize available components. The aspect of appeal relates to the presentation of the material and the product's appearance, while the aspects of efficiency and usefulness reflect students' assessments of the e-module as a learning resource. The involvement of students with high, moderate, and low academic ability levels provides an initial insight into the product's use by students with different ability characteristics. These results align with the study by [33], which involved students with varying academic ability levels in evaluating the practicality of e-modules based on cognitive conflict. Additionally [26] also emphasized the importance of assessing validity and practicality in e-module development. These similarities indicate that user evaluations are necessary to obtain information regarding the product's ease of use and usability. However, one-on-one evaluations involving a limited number of students cannot fully represent the experiences of all students with diverse characteristics and learning conditions. Therefore, the students' usability results in this study serve as an initial assessment of the product's usability and provide a basis for identifying areas that still require improvement.

Teachers' assessments of practicality also indicate that e-modules can be used as supplementary teaching materials for physics instruction based on their ease of use, appeal, efficiency, and benefits. Teachers' assessments complement students' responses because teachers can evaluate how well the learning activities align with learning objectives, the consistency of material presentation, and the ease of using the product to support learning activities. These results indicate that e-modules have the potential to serve as an alternative digital teaching resource that supports structured learning and independent study. This aligns with [22], who position formative evaluation as a crucial component in the development of educational products to gather feedback and refine the design. Although the results of teacher and student evaluations provide a positive outlook on the product's practicality, this study remains limited to expert validation and an initial practicality evaluation conducted through a one-to-one phase. The study has not yet included small-group evaluations or field tests; therefore, the product's applicability in broader learning contexts remains unknown. Furthermore, the effectiveness of the e-module in remediating misconceptions cannot yet be concluded, as no testing of changes in students' understanding categories has been conducted before and after instruction. Thus, the results of this study provide preliminary evidence regarding the validity and practicality of a cognitive conflict-based e-module that integrates deep learning and local wisdom in the topic of sound waves. Further research is needed to test the product in larger groups and to empirically evaluate changes in students' understanding and misconceptions.

IV. CONCLUSION

A cognitive conflict-based e-module integrating deep learning and local wisdom on the topic of sound waves has been successfully developed in the form of digital instructional materials based on Google Sites. The characteristics of the e-module lie in the application of the four stages of cognitive conflict, the integration of the principles of mindful learning, meaningful learning, and joyful learning, as well as the use of the local wisdom of Nagari Surian as the learning context. The research results indicate that the e-module has been evaluated and meets the criteria for high validity and high practicality based on assessments by experts, students through one-on-one evaluations, and two physics teachers. Thus, the research objectives of developing the e-module and evaluating its validity and practicality have been achieved. However, this study has not yet tested the effectiveness of the e-module in remediating students' misconceptions. Therefore, future research is recommended to conduct an effectiveness test to determine the e-module's contribution to the remediation of misconceptions regarding sound waves.

REFERENCES

[1] Hidayatullah, Z., Jumadi, J., Nadhiroh, N., Kartika, E., Nuha, A. A., & Erlangga, S. Y. (2020). *Identifikasi miskonsepsi dan konflik kognitif fisika: kasus terkait perubahan konseptual. Edusains,* 12(1), 64-71.

[2] Maulidyah, R. L., & Zainuddin, A. (2022). Implementasi tes formatif berbasis multirepresentasi untuk analisis pemahaman konsep siswa. *Jurnal penelitian pembelajaran fisika, 13(1), 1-8*.

[3] Mufit, F., Asrizal, A. & Puspitasari, R. 2020. Meta-Analysis Of The Effect Of Cognitive Conflict On Physics Learning. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 6(2): 267–278*.

[4] Mufit, F., & Fauzan, A. (2019). *Model pembelajaran berbasis konflik kognitif (PbKK) Disertai Penerapan Remediasi Miskonsepsi pada Sain dan Matematika*. Malang: CV IRDH.
[5] Wahyono, U., Hermanto, I. M., Nurhayati, N., Samatowa, L., Mohamad, W. M., & Maharani, N. L. S. (2023). Pengembangan Tes Diagnostik untuk Mengidentifikasi Pemahaman Konsep Siswa SMA pada Pokok Bahasan Gelombang Bunyi. *Jambura Physics Journal, 5(1), 67-79.*
[6] Haerunnisa, H., Prasetyaningsih, P., & Biru, L. T. (2022). Analisis miskonsepsi siswa SMP pada konsep getaran dan gelombang. *PENDIPA Journal of Science Education, 6(2), 428-433*.
[7] Ansyah, T. A., Kusairi, S., Supriana, E., & Ibad, M. I. (2021). *Profil miskonsepsi siswa sma pada materi gelombang mekanik* (Doctoral dissertation, State University of Malang).
[8] Sadiman, A. S., dkk. (2006). *Media Pendidikan: Pengertian, Pengembangan, dan Pemanfaatannya*. Jakarta: PT RajaGrafindo Persada.
[9] Agustina, D., & Mufit, F. (2023). Analysis of students' misconceptions about thermodynamics material and their perceptions of augmented reality as a cognitive conflict-based teaching material. *Journal of Innovative Physics Teaching, 1(2), 146–154*
[10] Anelfia, S. C., & Mufit, F. (2023). Analysis of Needs Design of Cognitive Conflict-Based Teaching Materialis Integrated Augmented Reality on Material Sound Wave. *Journal of Innovative Physics Teaching, 1(2), 129-135.*
[11] Yuli, F., & Mufit, F. (2021). Disain dan validitas bahan ajar berbasis konflik kognitif mengintegrasikan virtual laboratory pada materi optik untuk meningkatkan pemahaman konsep siswa sma/ma. *Jurnal Penelitian Pembelajaran Fisika, 7(1), 101-112.*
[12] Faresta, R. A., & Kosim, G. (2020). Pengembangan Modul Pembelajaran Fisika Berbasis Pendekatan Konflik Kognitif. *Applied Science and Technology, 1(3), 88-95.*
[13] Feriyanto, F., & Anjariyah, D. (2024). Deep learning approach through meaningful, mindful, and joyful learning: A library research. *Electronic Journal of Education, Social Economics and Technology, 5(2), 208-212.*
[14] Mokodongan, A. P. B., Arbie, A., & Samatowa, L. (2025). Remediasi miskonsepsi menggunakan pendekatan deep learning dan KIT gelombang dan termodinamika. *Jurnal Pendidikan Matematika dan Sains, 14(1)*
[15] Annisha, D. (2024). Integrasi penggunaan kearifan lokal (local wisdom) dalam proses pembelajaran pada konsep kurikulum merdeka belajar. *Jurnal Basicedu, 8(3), 2108-2115.*
[16] Wiyono, K., Ismet, I., Andriani, N., Fitonia, A., Nadia, H., Meitasari, D., & Nazhifah, N. (2024). Exploration of physics concepts in local wisdom of South Sumatera as an effort to develop students' 21stcentury skills. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 10(1), 61–78.*
[17] Fitriah, L., Yuliati, L., Parno, P., Sunaryono, S., & Taufiq, A. (2025). Indonesian local wisdom-based physics learning: Strategy and media. *Journal of Education Culture and Society*. https://doi.org/10.15503/jecs2025.2.335.364
[18] Sari, A. M., Syeilendra, S., & Hidayat, H. A. (2023). Jejak falsafah Alam Takambang Jadi Guru dalam repertoar musik tradisional Minangkabau. *Satwika: Kajian Ilmu Budaya dan Perubahan Sosial,* 7(1), 143–152. https://doi.org/10.22219/satwika.v7i1.25242
[19] Nursyirwan. (2011). *Varian teknik penalaan talempong logam di Minangkabau* [Disertasi doktoral, Universitas Gadjah Mada].
[20] Afrizon, R., Dewi, W. S., & Dwiridal, L. (2020). Analysis of physics parameters on aerophone musical instruments from Minangkabau as context meaningful learning. *Journal of Physics: Conference Series, 1481, Article 012109.* https://doi.org/10.1088/1742-6596/1481/1/012109
[21] Salsabila, K. Y., Mufit, F., Ratnawulan, & Emiliannur. (2026). Design of an interactive e-module based on cognitive conflict and deep learning approach for remediating students' misconceptions on light wave concepts. *Pillar of Physics Education, 19(4), 358–376*.
[22] Plomp, T., & Nieveen, N. (2013). Educational Design Research.
[23] Firdausi, R. F. (2023). *Pengembangan instrumen five-tier diagnostic test berbasis higher order thinking skills (5TDT-HOTS) berorientasi PISA pada materi gelombang bunyi*. Universitas Islam Negeri Walisongo Semarang.
[24] P. D. Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif dan R & D*. 2017.
[25] H. Retnawat.. *Analisis Kuantitatif Instrumen Penelitian (Panduan Peneliti, Mahasiswa, Dan Psikometrian).* Yogyakarta:Parama Publishing.2016
[26] K. Anshari, K. Rukun, and A. Huda, "Validitas dan Praktikalitas E-Modul Pelatihan Mikrotik Guru Teknik Komputer," *J. Resti (Rekayasa Sist. dan Teknol. Informasi), vol. 3, no. 3, pp. 538–543, 2019*.

[27] Halim, A., Soewarno, S., Elmi, E., Zainuddin, Z., Huda, I., & Irwandi, I. (2020). The impact of the E-Learning module on remediation of misconceptions in modern physics courses. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 6(2), 203-216.*
[28] Kemendikdasmen. (2025). *Panduan pengembangan kurikulum pendidikan edisi revisi tahun 2025*.
[29] Nanto, D., Nurlaela, A., Putri, D. S. I., Amatullah, N. S., Suartini, K., & Solehat, D. (2022). Saron Musical Instruments to Improve Creative Thinking Skills in Learning the Concept of Sound Waves. *International Journal of Active Learning, 7(1), 137-148.*
[30] Direktorat Pembinaan Sekolah Menengah Atas. (2008). *Panduan Pengembangan Bahan Ajar*. Jakarta: Depdiknas.
[31] Tania, Bangun, A. A., Sinuraya, O. P., Sitorus, S. A., & Fitri, S. (2025). Literature study: Students' misconceptions on sound waves. *Jurnal Penelitian Pendidikan, 42*(2). https://doi.org/10.15294/jpp.v42i2.36722
[32] Nugraha, D. A. (2025). Using four-tier diagnostic test to identify misconceptions about mechanical and light waves. *Jurnal Pengajaran Matematika dan Ilmu Pengetahuan Alam, 30*(1). https://doi.org/10.18269/jpmipa.v30i1.80861
[33] Rahmi, Z., & Mufit, F. (2025). Design and validity of e-modules based on cognitive conflict in measurement materials for grade X senior high school/madrasah aliyah. *Physics Learning and Education, 3*(4). https://doi.org/10.24036/ple.v3i4.288
[34] Sriwahyuni, E. (2024). Identifikasi Konsep Ipa Fisika Dalam Pembuatan Alat Musik Tradisional Tennong-Tennong. *Journal of Syntax Literate, 9(2), 753.*
[35] Louven, C. (2023). The ‘talempong batu’lithophone of Talang Anau (West Sumatra) and its astonishing tuning system. *Journal of Music Archaeology, 1, 249-260.*