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

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ABSTRACT

Misconceptions regarding thermodynamics pose a challenge in physics education because students still struggle to understand the relationship between heat, internal energy, and work in thermodynamic processes. This study aims to develop a cognitive conflict-based e-module that integrates deep learning and local wisdom on thermodynamics that is valid and practical as instructional material to support efforts to remediate students' misconceptions. This study employed a development research design based on Plomp's model, encompassing the preliminary research, development or prototyping, and assessment phases. The study was limited to testing the validity and practicality of the product. Participants included 34 eleventh-grade students in the needs analysis, three experts in the validation stage, three students with high, moderate, and low levels of understanding in the one-to-one stage, and two physics teachers in the practicality assessment. Data were collected through needs analysis, self-evaluation, expert validation forms, and student and teacher practicality assessment forms. Product validity was analyzed using Aiken's V index, while practicality was analyzed based on the percentage of scores obtained. The e-module was developed using Google Sites by integrating cognitive conflict stages, deep learning principles of mindful, meaningful, and joyful learning, and Riau's local wisdom. The expert validation results showed that the e-module achieved an average Aiken's V of 0.93, falling into the highly valid category. The one-to-one evaluation results showed an average practicality score of 93.84%, categorized as very practical. Meanwhile, the practicality assessment by teachers yielded an average score of 95.93%, also categorized as very practical. These results indicate that the developed e-module meets the criteria of high validity and practicality as instructional material for thermodynamics. However, its effectiveness in remediating students' misconceptions has not yet been tested and requires further research.

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

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I. INTRODUCTION

Physics is the science that studies natural phenomena through an understanding of concepts, principles, laws, and relationships between physical quantities. One area of physics closely related to daily life is thermodynamics, which encompasses the concepts of temperature, heat, work, internal energy, and the laws of thermodynamics. These concepts are interrelated, so students need to understand their physical meanings and the relationships between physical quantities, rather than merely memorizing definitions or using mathematical equations. [1] explains that thermodynamic concepts can be found in everyday activities, such as cooking, drying clothes, using a thermos, and operating a vehicle's engine. However, everyday experiences do not always lead to an understanding that aligns with scientific concepts. [2] reveals that the concepts of temperature and heat are among those that have the potential to cause misconceptions because students already have prior understandings before receiving formal instruction.

Misconceptions are concept understandings that do not align with scientific concepts and can hinder the physics learning process. In thermodynamics, misconceptions can arise regarding the ideal gas concept, the First and Second Laws of Thermodynamics, work, heat, and various thermodynamic processes [3]. These difficulties can lead students to inaccurately explain physical phenomena and fail to understand the relationships between heat, work, temperature, and energy changes within a system. Therefore, instruction is needed that not only emphasizes the delivery of content but also helps students identify their prior understandings and re-examine the concepts they hold. One approach that can be taken is to implement a cognitive conflict-based learning model. This model encourages students to compare their prior understandings with phenomena or scientific evidence that contradicts their ideas, thereby giving them the opportunity to evaluate those understandings based on correct physics concepts [4].

The cognitive conflict model encourages students to reexamine their prior understandings when confronted with phenomena or information that does not align with their existing ideas. [5] explains that cognitive conflict learning involves the activation of preconceptions and misconceptions, the presentation of cognitive conflicts, the discovery of concepts and equations, and reflection. These stages provide students with the opportunity to identify their initial understanding, confront conceptual conflicts, build understanding based on scientific concepts, and reflect on their learning outcomes. A study [6] on an interactive e-module based on the cognitive conflict model for the concept of force also demonstrates the relevance of this approach in the development of instructional materials designed to address students' misconceptions.

The cognitive conflict model is implemented through four stages: activation of preconceptions and misconceptions, presentation of cognitive conflict, discovery of concepts and similarities, and reflection [5]. These four stages provide students with the opportunity to identify their prior understanding, confront conceptual conflicts, build understanding based on scientific concepts, and reflect on their learning outcomes. This model has been applied in the development of instructional materials for various physics topics. In [6], it was found that an interactive e-module based on cognitive conflict regarding the concept of force received an expert validation score of 85.6, classified as "highly valid." Furthermore, a study [7] found that interactive multimedia based on cognitive conflict can enhance students' critical thinking and creativity skills to a high degree, while communication and collaboration skills improved to a moderate degree. Statistical test results also indicated a significant effect on the improvement of these four skills. Meanwhile, [8] found that cognitive conflict-based augmented reality media integrated with STEM on the topic of Newton's Law of Universal Gravitation achieved a validity score of 0.945, classified as "valid," and met the criteria for being "highly practical." Its use also improved students' science literacy with an N-gain score of 59% in the "moderate" category and demonstrated a significant effect. Furthermore, a study [9] found that a cognitive conflict-based e-module on measurement met high validity criteria. These various research findings demonstrate that the cognitive conflict model has been applied in the development of digital instructional materials and has produced products that support the development of students' understanding and skills across various physics topics.

The development of cognitive conflict-based instructional materials has also begun to be integrated with the deep learning approach. [10] developed an interactive e-module based on cognitive conflict that is integrated with the deep learning approach on the topic of light waves and obtained results classified as highly valid and highly practical. The deep learning approach in learning emphasizes three main principles: mindful, meaningful, and enjoyable. Mindful learning encourages students to recognize their prior understanding and become aware of their learning process; meaningful learning connects new knowledge with experiences and real-world phenomena; while joyful learning creates engaging and motivating learning experiences. [11] emphasizes the importance of analysis, reflection, and problem-solving activities related to real-world phenomena in the deep learning approach. In line with this, [12] explains that these three principles emphasize the connection between new knowledge and prior understanding, attention during the learning process, and the creation of a motivating learning environment. The integration of deep learning principles with the cognitive conflict model is expected to support student engagement in recognizing, evaluating, and constructing conceptual understanding.

The deep learning approach can also be supported by integrating local wisdom as a learning context. Local wisdom encompasses community knowledge and activities that can be linked to scientific concepts, thereby bringing learning closer to students' lives. The importance of connecting knowledge learned in school with phenomena students encounter in their daily lives is also emphasized in [13]. In thermodynamics, Riau's local wisdom can be integrated through palm oil processing activities, which involve heating and the use of steam for sterilizing fresh fruit bunches. Additionally, the use of wood-fired stoves in community cooking can be linked to the conversion of chemical energy into thermal energy, heat transfer, and heating processes. These phenomena can serve as a context to guide students in observing events, identifying relationships between physical

quantities, and explaining the processes that occur based on thermodynamic concepts. Thus, local wisdom not only serves as a supplement to the curriculum but becomes an integral part of learning activities that support contextual conceptual understanding.

The development of digital instructional materials is one alternative for systematically organizing content and learning activities. Google Sites can be utilized as a platform for developing e-modules that allow for the presentation of content through the integration of text, images, videos, simulations, quizzes, and learning links [14]. The use of this platform enables content, contextual phenomena, learning activities, and reflections to be organized within a single digital learning environment. Furthermore, [15] indicates that the results of a needs analysis identified students' misconceptions regarding temperature and heat and the need for instructional materials that support improved conceptual understanding. These findings highlight the importance of developing instructional materials based on learning challenges and student needs.

Although various previous studies have developed instructional materials based on cognitive conflict, integrated deep learning approaches, or utilized digital technology in physics education, these studies have been conducted on different topics and in different forms of development. Studies [6] and [9] focused on developing cognitive conflict-based instructional materials on the topics of force and measurement, while [10] integrated cognitive conflict and deep learning in the topic of light waves. Study [8] also utilized augmented reality technology and a STEM approach in the topic of gravity. Based on these studies, there remains a need to develop an e-module on thermodynamics that comprehensively integrates the stages of cognitive conflict, the three principles of deep learning (mindfulness, meaningfulness, and enjoyment), and the local wisdom of Riau. This integration distinguishes this study because the context of local wisdom is utilized to connect phenomena in community life with thermodynamic concepts in learning activities, rather than merely being presented as supplementary information. Furthermore, product development is guided by student needs and evaluated through expert validation as well as practical assessments by students and teachers.

The e-module was developed systematically using Plomp's model, which includes preliminary research, development or prototyping, and evaluation [16]. These stages enabled the product to be designed based on needs analysis and literature review, then evaluated and refined through self-evaluation, expert assessment, and practical testing. Validity assessment is necessary to determine the appropriateness of the content, visual communication, instructional design, and software utilization. Meanwhile, practicality assessment is conducted to gather information regarding the product's ease of use, appeal, efficiency, and benefits for students and teachers.

Based on the above description, this study aims to describe the characteristics of a cognitive conflict-based e-module that integrates the deep learning approach and Riau's local wisdom into thermodynamics material, analyze the validity of the e-module based on expert evaluations, and analyze the practicality of the e-module based on student and teacher evaluations. The e-module was developed using Google Sites as the development platform by integrating the stages of cognitive conflict, deep learning principles which include being conscious, meaningful, and enjoyable as well as the context of Riau's local wisdom. The product was designed to support efforts to remediate students' misconceptions regarding thermodynamics. This study was limited to testing validity and practicality; therefore, the product's effectiveness in addressing misconceptions was not part of the evaluation.

II. METHOD

This study is a research and development (R&D) project aimed at producing a cognitive conflict-based e-module integrated with a deep learning approach and local wisdom to remediate students' misconceptions regarding thermodynamics. Product development was conducted using the Plomp model proposed by [16], which consists of three phases: preliminary research, development or prototyping, and assessment. This study was limited to testing the validity and practicality of the product. The activities carried out in each development phase are as follows.

Preliminary Research

The preliminary research phase is the initial stage conducted to identify learning problems and the theoretical foundations used in the development of e-modules. This phase includes the following activities.

Needs and Context Analysis

A needs and context analysis was conducted to gather information regarding the state of physics learning, particularly regarding thermodynamics. Information was obtained through questionnaires and interviews with physics teachers to understand the ongoing learning process, the teaching methods used, the availability and utilization of instructional materials, and the difficulties students experienced in understanding thermodynamic concepts. In addition, student misconceptions were identified using the Four-Tier Diagnostic Test administered to 34 11th-grade students at SMA N 4 Dumai. The participating students were 11th-graders who had already studied thermodynamics. The test consisted of 10 items, each with four levels: answer choice, level of confidence in the answer, reason selection, and level of confidence in the reason. Test results were analyzed based on a combination of answer accuracy and the accuracy of students' confidence levels to categorize their understanding into "conceptual understanding," "misconceptions," and "lack of conceptual understanding." The results of the interviews and diagnostic tests were used to identify learning issues and determine the need for e-module development.

Literature Review

The literature review was conducted by collecting and examining various scientific sources, such as journal articles, books, and relevant research findings. The review covered students' misconceptions regarding thermodynamics, cognitive conflict-based learning, the deep learning approach, the integration of local wisdom into physics education, and the development of digital instructional materials. In addition, the characteristics and stages of cognitive conflict-based learning that can help students recognize the discrepancy between their prior understanding and scientific concepts were examined. The results of the literature review were used as a foundation for determining the learning approach, designing the content, selecting local wisdom phenomena, and defining the components and characteristics of the e-module being developed.

Development or Prototyping Phase

Product Design

Product design was carried out by structuring the e-module's components based on the learning outcomes and learning objectives for the thermodynamics material. The components include the title page, user guide, content, learning activities, worksheets, assessment, and author profile. The e-module was developed using Google Sites by integrating the four stages of cognitive conflict: activation of preconceptions and misconceptions, presentation of cognitive conflict, discovery of concepts and equations, and reflection. In addition, the principles of deep learning which include being conscious, meaningful, and enjoyable as well as the local wisdom of Riau were integrated into the learning activities. The result of this design is an initial prototype of the e-module.

Self-Evaluation

Self-evaluation is conducted by reviewing the initial prototype of the e-module before it is validated by experts. At this stage, a self-evaluation checklist is used as a tool to assess and review the product's initial feasibility. The sheet covers aspects such as the accuracy of the material, the completeness of components, the appropriateness of cognitive conflict syntax, the integration of deep learning and local wisdom, as well as the appearance and navigation. The review is conducted by comparing each component of the e-module against the criteria listed on the evaluation sheet. Any sections that do not meet the criteria are then revised to produce a prototype that is better prepared to enter the expert validation stage.

Expert Validation (Expert Review)

Expert validation involved three validators who assessed the e-module's suitability using a validation sheet. The assessment covered four aspects: content substance, visuals, instructional design, and software. The content substance aspect pertains to the accuracy and alignment of the thermodynamics material with the learning objectives. The visual communication aspect relates to readability, layout, and the presentation of visual elements. The instructional design aspect relates to the alignment of objectives, activities, and stages of cognitive conflict, as well as the integration of deep learning principles and local wisdom. Meanwhile, the software utilization aspect relates to the use of Google Sites in presenting the e-module's components and navigation. The evaluation was conducted using a five-point Likert scale based on [17], namely strongly disagree, disagree, undecided, agree, and strongly agree. Each response option was scored sequentially from 1 to 5. In addition to

assigning scores, the validators also provided comments and suggestions regarding the product. The validation results were analyzed using Aiken's V index to determine the e-module's validity level. Revisions were made based on the assessment results and feedback from expert validators. Improvements covered aspects of content, language, visual presentation, instructional design, and navigation functions. These improvements resulted in a refined prototype ready to proceed to the next phase of assessment through one-on-one evaluations and practical testing.

Assessment Phase

One-to-one Evaluation

One-to-one evaluations were conducted with three 11th-grade students from SMA N 4 Dumai, representing high, medium, and low academic ability levels. This phase involved only three students. The students were asked to use the e-module directly to study the material and participate in the available learning activities. During the activity, observations were made regarding the readability of the material, the clarity of the usage instructions, the ease of navigation, and the students' experience in using the e-module. The results of the one-on-one evaluation were used to identify parts of the product that still required improvement based on user experience.

Practicality

A practicality test was conducted to determine the ease and feasibility of using the e-module in learning. The test was carried out by distributing a practicality questionnaire to students and two physics teachers at Dumai State High School 4. The assessment involved three students with high, moderate, and low academic abilities, as well as two physics teachers at SMA N 4 Dumai. The students' evaluations covered the ease of use, appeal, efficiency, and benefits of the e-module. Meanwhile, the teachers' evaluations covered the ease of use, appeal, efficiency, and benefits of the e-module in supporting the learning process. The survey results were analyzed to determine the product's level of practicality based on the students' and teachers' evaluations.

Data Analysis Techniques

The validity of the resulting product was evaluated through a questionnaire completed by faculty members from the Department of Physics at Padang State University. Product validity was assessed using a Likert scale questionnaire based on [17]. This scale consists of five response options, ranging from "strongly disagree," "disagree," "undecided," "agree," to "strongly agree." The validation data were analyzed using Aiken's *V* index with the following formula.

$$V = \frac{\sum s}{n(c-1)} \quad (1)$$

$$s = r - l_0 \quad (2)$$

Note:

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 value is then interpreted based on the validity criteria used in the study.

Table 1 Decisions Based on Aiken's *V* Index

Interval	Category
≤ 0,4	Insufficiently Valid
0,4 ≤ V ≤ 0,8	Valid
0,8 ≤ V ≤ 1	Highly Valid

(Source: [18])

These criteria were used to determine the validity level of the e-module and served as the basis for revisions based on feedback from three expert validators. After the revisions, a one-on-one evaluation was conducted with three students one with high academic ability, one with moderate ability, and one with low ability to assess the e-module's readability, usage instructions, navigation, and user experience. Next, practicality was assessed through a questionnaire administered to students and two physics teachers at SMA N 4 Dumai, with evaluation aspects including ease of use, appeal, efficiency, and benefits. Practicality data were analyzed based on the percentage of the score obtained relative to the maximum score using the following formula.

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

The practicality of the e-module was determined based on the percentage of the assessment results from the practicality questionnaire. These results were categorized into several categories: very practical, practical, fairly practical, less practical, and impractical [19]. This categorization was used to determine the level of practicality of the e-module based on students' and teachers' assessments of its use in learning.

III. RESULT AND DISCUSSION

RESULT

This study is a research and development (R&D) project aimed at producing an e-module based on cognitive conflict that integrates deep learning and local wisdom to remediate students' misconceptions regarding thermodynamics. The development of this e-module utilized Plomp's development model, which consists of three stages: preliminary research, development or prototyping, and assessment phase. Each stage was carried out systematically to produce a product aligned with learning needs and student characteristics.

Preliminary Research Phase

Needs and Context Analysis

A needs and context analysis was conducted to identify thermodynamics learning issues that formed the basis for the e-module's development. Based on interview results, teaching still faces challenges in identifying and addressing students' misconceptions. Students tend to equate temperature with heat and view heat as energy that can be created. These findings indicate that learning challenges are not only related to mastering formulas but also to students' understanding of the meaning and relationships among thermodynamic concepts.

Misconceptions were identified using the Four-Tier Diagnostic Test, which was administered to 34 eleventh-grade students at Dumai State High School 4. The number 34 refers to the number of students who took the test, while 340 represents the total number of responses analyzed from all students for each test item. The diagnostic instrument consists of four tiers: accuracy of answers, level of confidence in answers, accuracy of reasoning, and level of confidence in reasoning. The subtopics used in the diagnostic test were determined based on the scope of thermodynamics material and the concepts that were the focus of instruction. These subtopics were selected to identify students' understanding of the interrelated core concepts of thermodynamics. Test results were analyzed based on a combination of students' answers and their confidence levels to categorize their understanding into "conceptual understanding," "misconceptions," and "lack of conceptual understanding."

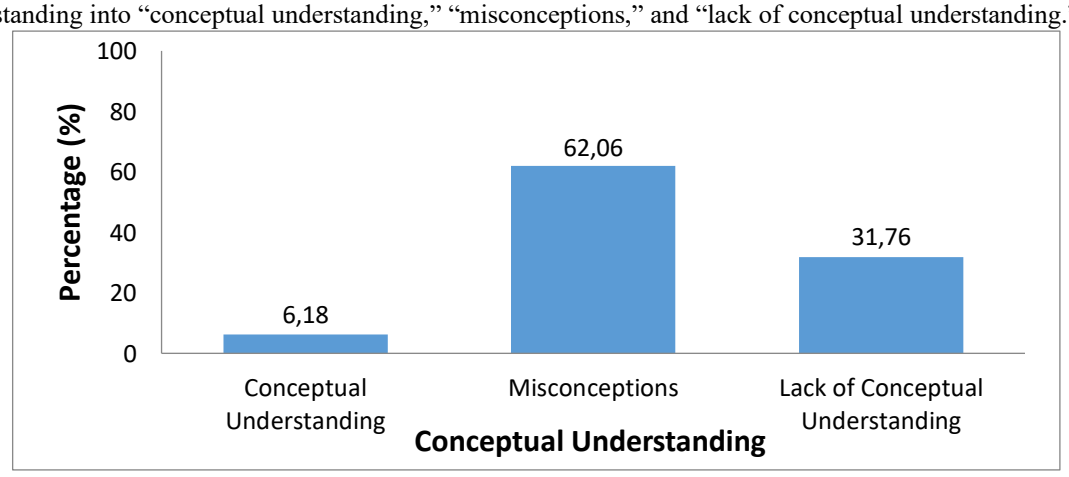


Figure 1. Results of Students' Conceptual Understanding

Based on Figure 1, of the 340 responses obtained through the diagnostic test, 211 responses (62.06%) were classified as misconceptions, 108 responses (31.76%) indicated that students did not understand the concepts, and only 21 responses (6.18%) fell into the "conceptual understanding" category. The graph shows that misconceptions are the most dominant category compared to the other two categories. The prevalence of misconceptions indicates a discrepancy between students' understanding and the scientific concepts they should grasp. Meanwhile, the large proportion of students who did not understand the concept indicates that some students do not yet have a sufficient understanding to explain thermodynamic phenomena. Thus, the initial problem identified cannot be adequately addressed merely by providing further explanations or practice problems; rather, it requires learning activities that help students recognize and evaluate their initial understanding.

A comparison of the three categories in Figure 1 also shows that the proportion of responses indicating conceptual understanding is still much smaller than the proportion of responses indicating misconceptions and lack of conceptual understanding. This finding is a critical consideration in determining the characteristics of the e-module being developed. The product must provide students with opportunities to express their initial ideas, compare them with relevant phenomena or evidence, and then learn the correct scientific explanations. The use of diagnostic tests in this study serves as a basis for determining development needs, not as evidence of the success of remediation. Therefore, these diagnostic results were used to guide the design of content, prompting questions, cognitive conflict activities, and reflection within the e-module.

In addition to examining the overall results, an analysis was conducted on the percentage of misconceptions in each thermodynamics subtopic. Analysis by subtopic is necessary because misconceptions do not always occur at the same rate across all concepts. This information helps identify concepts that require greater attention in the presentation of material and learning activities.

Table 2. Percentage of Misconceptions in Thermodynamics Subtopics

No.	Thermodynamics Subtopic	Percentage of Misconceptions (%)
1	Thermodynamic Work	76.4
2	Internal energy of a gas	67.6
3	Isochoric process	67.65
4	The First Law of Thermodynamics and Heat Engines	64.71
5	Thermodynamic Processes	61.76
6	Adiabatic process	55.88
7	Isobaric process	52.94
8	P–V diagram for an isochoric process	41.18

Table 2 shows that the highest percentage of misconceptions was found in the indicator for work in thermodynamics, at 76.4%, while the lowest percentage was found in the indicator for P–V diagrams in isochoric processes, at 41.18%. These percentages indicate that students still struggle with concepts that require an understanding of the relationships between work, heat, internal energy, and changes in the state of a system. These concepts are interrelated, so an inaccurate understanding of one quantity can affect the understanding of other concepts. The results of this needs analysis served as the basis for determining the direction of the e-module's development. The content and activities were designed so that students could revisit their initial ideas, encounter situations that challenge those ideas, discover scientific explanations, and engage in reflection. Thus, the needs analysis provided an empirical basis for the characteristics of the developed product, particularly in the selection of cognitive conflict models and the contextual presentation of thermodynamics material..

Literature Review

A literature review was conducted to establish a theoretical foundation for the development of a cognitive conflict-based e-module integrated with the deep learning approach and local wisdom.

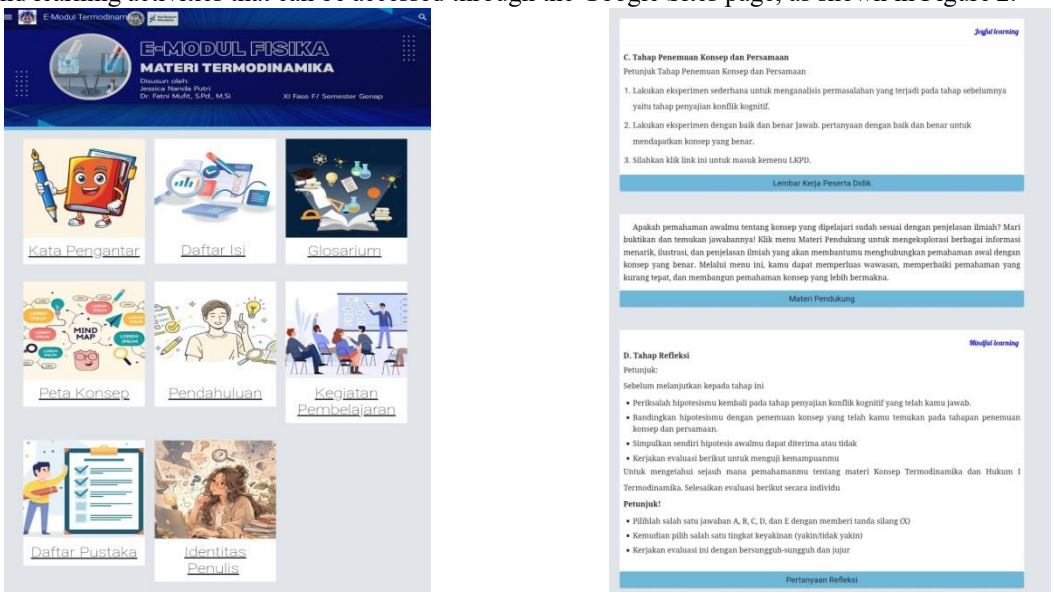
Table 3. Literature Review

Research	Research Findings	Differences in Research
Pratama et al. (2021)	Developed an interactive e-module based on cognitive conflict to remediate students' misconceptions regarding the concept of force.	Did not integrate a deep learning approach with Riau's local wisdom.
Salsabila et al. (2026)	Developing a cognitive conflict-based e-module integrated with deep learning on light waves, rated as highly valid and highly practical.	Has not integrated Riau's local wisdom and uses different content.
Sari et al. (2026)	Analyzed the need for e-modules integrating cognitive conflict, deep learning, and local wisdom and identified student misconceptions regarding temperature and heat.	Focused on analyzing the needs for temperature and heat materials, whereas this study produced an e-module on thermodynamics.
Mokodongan, Arbie, and Samatowa (2026)	Discussed the remediation of misconceptions using a deep learning approach and KIT on waves and thermodynamics.	Using the KIT, this study developed an e-module that integrates cognitive conflict and local wisdom from Riau.

Development or Prototyping Phase

Product Design

The product developed is a physics e-module on thermodynamics using Google Sites as the development platform. The e-module is designed to help students learn concepts step by step through the presentation of material, learning activities, experiments, and reflection. The product's key feature lies in the application of a cognitive conflict-based learning model (PbKK) integrated with deep learning principles and the local wisdom of Riau. In terms of visual design, blue was chosen as the dominant color to convey a sense of calm and appeal, as well as to create visual consistency across every page. The layout is designed to be simple and structured so that information is easy to read and navigation between menus is clear. The structure of the e-module consists of several menus: preface, table of contents, glossary, concept map, introduction, learning activities, bibliography, and author information. Each menu is organized according to its function to help students follow the learning flow systematically. The presentation of the material is supplemented with text, illustrations, videos, supporting links, and learning activities that can be accessed through the Google Sites page, as shown in Figure 2.



a) b)

Figure 2. a) E-Module Cover b) Application of Cognitive Conflict and Deep Learning

The next key characteristic is the application of the PbKK model syntax, which is organized sequentially and includes the activation of preconceptions and misconceptions, the presentation of cognitive conflict, the discovery of concepts and equations, and reflection. During the preconception and misconception activation stage, students are guided to take a diagnostic test to identify their initial understanding. The test results serve as a basis for students to recognize concepts they have already understood as well as those that still need

improvement. Next, during the cognitive conflict presentation stage, students are presented with phenomena that can create a conflict between their initial understanding and scientific explanations.

After experiencing cognitive conflict, students are guided to the stage of discovering concepts and equations through experiments, observations, completing student worksheets (LKPD), and analyzing the results of these activities. These activities provide students with the opportunity to compare their initial hypotheses with observational results and relate them to the thermodynamic concepts being studied. During the reflection stage, students are encouraged to review their understanding after participating in the learning activities. Thus, the PbKK syntax is not only used as a sequence for presenting material but also serves as the foundation for organizing students' learning experiences from identifying prior knowledge to reviewing the concepts they have learned.

In addition to implementing the PbKK model, the e-module integrates the principles of deep learning, which include mindful learning, meaningful learning, and joyful learning. The principle of mindful learning is applied through activities that encourage students to identify their prior knowledge, pay attention to their thought processes, and reflect on their learning outcomes. The principle of meaningful learning is realized through the presentation of contextual phenomena and problems that help students connect thermodynamic concepts to observable situations in daily life. Meanwhile, the principle of joyful learning is supported by the use of illustrations, videos, experiments, and activities that directly engage students. The integration of these three principles is expected to make learning activities more focused, relevant, and engaging for students.

Another characteristic of the product is the integration of Riau's local wisdom as a context for thermodynamics learning activities. The local wisdom integrated includes the process of making durian lempuk, making lemang, and the utilization of palm oil mills. In the production of durian lempuk, the process of heating and stirring the dough for a specific period is linked to the concepts of systems and environments specifically, the durian lempuk dough as the system, while the container and its surrounding environment serve as the environment. The process of heating the dough is also linked to the concepts of heat and temperature change. In the preparation of lemang, the use of bamboo as a container and the use of fire in the cooking process are linked to the concept of heat transfer. Meanwhile, the operation of a palm oil mill specifically the heating process and the use of steam in the processing of fresh fruit bunches is linked to the concepts of heat, work, and energy transformation within a system. Through the presentation of these phenomena, students are guided to observe events closely related to community life, identify the physics concepts involved, and explain the phenomenon based on thermodynamic concepts. Overall, the e-module design combines a systematic digital structure, PbKK syntax, deep learning principles, and the context of Riau's local wisdom into a single learning sequence. Google Sites serves as the platform that organizes these various components, while diagnostic activities, the presentation of conflicts, experiments, concept discovery, and reflection form part of the students' learning pathway. This integration is a key feature of the product design, developed to support thermodynamics learning and help students review their understanding as well as their misconceptions.

Self-Evaluation

Self-evaluation is conducted to verify the prototype's alignment with the established design before the product is assessed by validators. This evaluation covers the e-module, its components, the e-module design, the syntax of cognitive conflicts, the integration of deep learning, and the integration of local wisdom. This stage is important because it allows developers to identify areas that need improvement early on, whether in terms of the completeness of components, the organization of content, or the consistency of the learning approach.

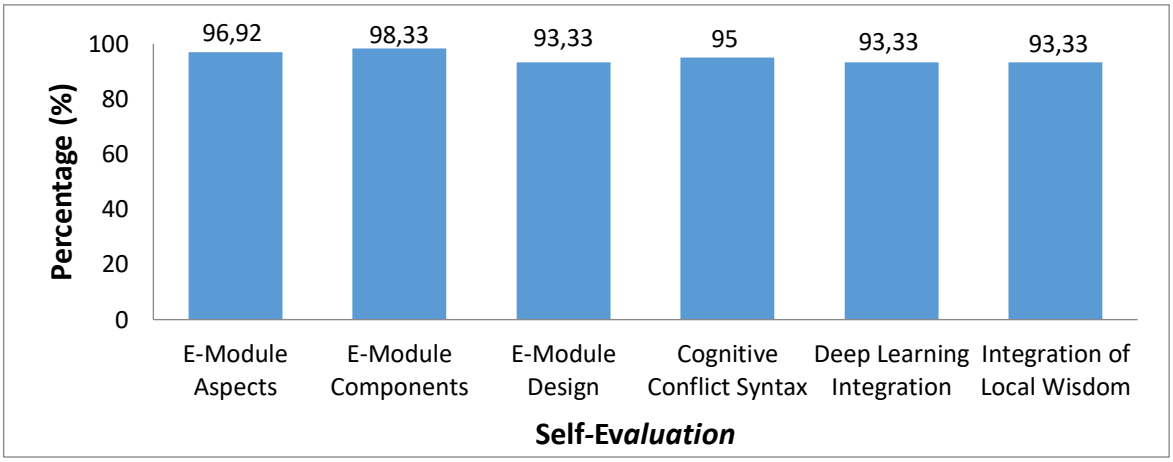


Figure 3. Self-Evaluation Results

Based on Figure 3, the self-evaluation results show that the e-module aspect scored 96.92%, e-module components scored 98.33%, e-module design scored 93.33%, cognitive conflict syntax scored 95%, deep learning integration scored 93.33%, and the integration of local wisdom at 93.33%. The highest percentage was found in the e-module components aspect, while the lowest percentages were found in the e-module design, deep learning integration, and integration of local wisdom aspects. These results indicate that all aspects achieved percentages above 90%, although some aspects still require attention for product refinement, particularly regarding design presentation and the integration of the learning approach with local wisdom. Regarding the aspects of cognitive conflict syntax, deep learning integration, and integration of local wisdom, the self-evaluation results showed a high degree of alignment with the established design. These findings indicate that all three elements have been incorporated into the prototype's structure. However, the self-evaluation results cannot be treated as a substitute for expert validation, as the assessment was conducted by the developers on their own product. Therefore, self-evaluation serves as an initial review, while assessments regarding the accuracy of the content, the appropriateness of the instructional design, and the quality of presentation are subsequently reinforced through expert validation.

Expert Validation (Expert Review)

Expert validation was conducted to determine the level of suitability of the developed e-module prototype based on the aspects established in the research instrument. The validation involved three lecturers from the Department of Physics at Padang State University, whose respective areas of expertise included instructional design, instructional content, and instructional media. The evaluation covered four aspects: content substance, visual communication, instructional design, and software utilization. These four aspects were used to assess the quality of the e-module, both in terms of the accuracy of the thermodynamics content and the presentation and instructional design that integrated the cognitive conflict model, the deep learning approaches, and local wisdom. The validators' assessment results were analyzed using Aiken's V validity index to determine the prototype's validity level for each aspect. The results of the expert validation for each aspect are presented in Table 4.

Table 4 Expert Validation Results

Evaluation Aspects	Evaluation Indicators	Aiken's V Value	Category
Content Substance	Accuracy, scope of content, timeliness, and readability	0.9219	Highly valid
Visual Communication Design	Navigation, typography, media, color, and layout	0.9323	Highly valid
Instructional design	Cover, introduction, learning competencies, content, characteristics of cognitive conflict, integration of deep learning and local wisdom	0.9253	Highly valid
Software utilization	Feedback and software utilization	0.9333	Highly valid
Average		0.9282	Highly valid

Based on Table 4, the expert validation results show that the e-module obtained an average Aiken's V score of 0.9282, falling into the "highly valid" category. The highest score was obtained in the aspect of software

utilization at 0.9333, while the lowest score was in the aspect of content substance at 0.9219. Although there were differences in scores across each aspect, all fell within the “highly valid” category. These results indicate that the e-module prototype has met the validity criteria based on the validators’ assessments of content substance, visual communication, instructional design, and software utilization. Although there were differences in scores across aspects, all aspects fell within the “highly valid” category. These results indicate that, based on the validators’ assessments, the prototype has met the validity criteria examined in this study.

Differences in scores across aspects provide information on which parts of the product require attention during revision. The assessment of content substance relates to the accuracy of concepts, the use of equations, and the alignment of explanations with learning objectives. Meanwhile, the aspects of visual communication and instructional design relate to readability, the organization of presentation, and the alignment of activities with the instructional design. The software utilization aspect pertains to the use of digital platforms to present various components of the product. Thus, the validation results are not only used to determine the feasibility category but also serve as the basis for refining the prototype. In addition to providing scores, the validators also offered suggestions for improvements to several parts of the product. These suggestions are used as a basis for refining the e-module prototype before proceeding to the next evaluation stage. Several examples of validator feedback along with the resulting revisions are presented in figure 4.

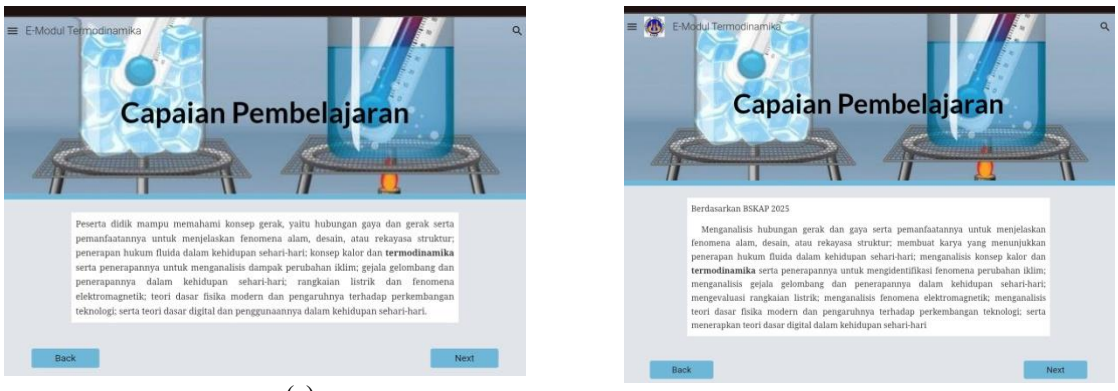


Figure 4. (a) Before revision (b) After revision

In the introduction section, revisions were made to the learning outcome statements based on the 2025 BSKAP document for Phase F. These adjustments were intended to ensure that the learning outcomes listed in the e-module comply with current curriculum regulations and are relevant to the thermodynamics material being developed. The learning outcome statements were updated to reflect the competencies that students are expected to master, thereby serving as an appropriate foundation for the development of learning objectives and activities in the e-module.

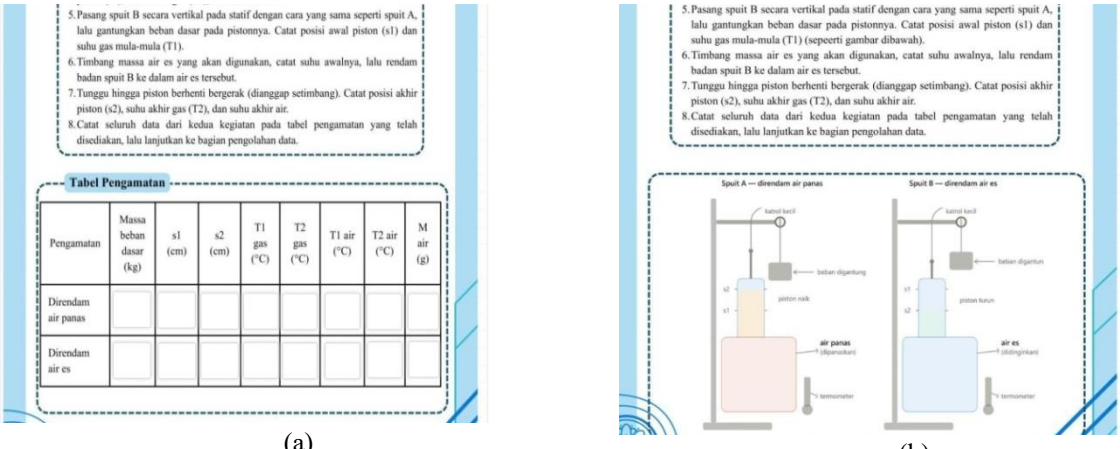


Figure 5. (a) Before revision (b) After revision

Revisions to the Worksheets (LKPD) were made by adding illustrations for each stage of the experiments presented. These illustrations are accompanied by captions or brief explanations to help students understand the equipment, materials, and procedures to be followed during the experiment. The addition of illustrations is also intended to make the steps in the worksheets easier to understand and follow systematically. Consequently, the presentation of the worksheets becomes clearer and supports student engagement in learning activities.

One-to-One Evaluation

The one-to-one evaluation was conducted by involving three students representing high, medium, and low academic ability levels. This evaluation aimed to gather preliminary information regarding the readability of the material, the clarity of instructions, ease of navigation, and the user experience with the e-module. Involving students with different ability levels provided an opportunity to verify whether the information and instructions in the product could be followed by users with diverse characteristics. After using the e-module, the three students provided feedback through a usability questionnaire covering ease of use, appeal, efficiency, and benefits.

Table 5 One-to-One Results

Evaluation Aspects	Student (%)	Category
Ease of Use	94.44	Very practical
Appeal	96.67	Very practical
Efficiency	91.67	Very practical
Benefits	92.59	Very practical
Average	93.84	Very practical

Based on Table 5, the results of the practicality assessment by three students yielded an average of 93.84%, falling into the very practical category. The appeal aspect received the highest percentage at 96.67%, indicating that the e-module's appearance and presentation are appealing to students. The ease of use aspect received a percentage of 94.44%, while the benefit aspect received 92.59%. These results indicate that the e-module is easy to use, has an attractive design, and provides benefits in supporting the thermodynamics learning process.

Meanwhile, the efficiency aspect received the lowest percentage 91.67% though it still falls within the very practical category. This score relates to the e-module's presentation, which includes a variety of learning components, such as written material, illustrations, videos, supporting links, and worksheets. The diversity of these components provides students with the opportunity to study the material through various sources but also requires time to access and understand each section sequentially. Consequently, the efficiency aspect received a relatively lower percentage compared to the other aspects. Nevertheless, the overall assessment results indicate that the e-module met the highly practical criteria based on student evaluations.

Practicality of E-Modules as Assessed by Teachers

Teachers conducted a practicality assessment to determine the level of practicality of the developed e-module based on the aspects of ease of use, appeal, efficiency, and benefits. These four aspects were used to gain an understanding of the quality of the e-module's use from the teachers' perspective in supporting thermodynamics learning activities. This assessment also pertains to the use of Google Sites as the e-module development platform, which integrates content, cognitive conflict-based learning activities, a deep learning approach, and local wisdom. The results of the teachers' practicality assessment are presented in Table 6.

Table 6. Teachers' Practicality Assessment Results

Evaluation Aspects	Teachers (%)	Category
Ease of Use	96.67	Very practical
Appeal	97.00	Very practical
Efficiency	93.33	Very practical
Benefits	96.70	Very practical
Average	95.93	Very practical

Based on Table 6, the results of the practicality assessment by two physics teachers yielded an average of 95.93%, falling into the very practical category. The appeal aspect received the highest percentage at 97.00%, followed by benefit at 96.70% and ease of use at 96.67%. These results indicate that the e-module has an attractive design, supports the learning process, and is easy for teachers to use. Meanwhile, the efficiency aspect received the lowest percentage at 93.33%, but still fell within the very practical category.

The lower percentage for the efficiency aspect is related to the need for teachers to adapt the use of the e-module to the flow and time allocation of classroom instruction. The e-module includes stages of cognitive conflict, such as the activation of preconceptions and misconceptions, the presentation of cognitive conflict, the discovery of concepts and equations, and reflection. Each stage requires careful time management to ensure that all learning activities are carried out effectively. Teachers also need to guide students in completing the learning activities available in the e-modules. These factors are believed to have influenced the assessment of the efficiency aspect. Nevertheless, overall, the e-modules were still rated as highly practical by teachers for use in thermodynamics instruction.

DISCUSSION

This study produced a cognitive conflict-based e-module that integrates deep learning approaches and local wisdom to address students' misconceptions in thermodynamics. The development of this product was based on the results of preliminary research, which revealed the presence of student misconceptions, the use of lecture-based methods, and instructional materials that did not fully support conceptual understanding. The e-module was developed using Google Sites as the development platform, which includes content, worksheets, contextual phenomena, learning activities, and reflections. The presentation of the material is designed so that students not only receive information but can also review and reconstruct their initial understanding. This development is designed so that the presentation of digital material does not focus solely on the delivery of information. The results of this development align with [15], which identified students' misconceptions regarding temperature and heat and the need for instructional materials that can facilitate learning based on cognitive conflict, deep learning, and local wisdom. However, this study differs in the subject matter developed, namely thermodynamics. This strengthens the foundation for the development of e-modules designed to provide learning experiences that encourage students to re-examine their initial understanding.

The cognitive conflict model is implemented through four stages: the activation of preconceptions and misconceptions provides students with the opportunity to express their initial understanding. Next, the presentation of cognitive conflict introduces problems or phenomena that can create a discrepancy between students' initial understanding and scientific concepts. Through the concept and equation discovery stage, students are guided and directed to build understanding based on scientific explanations, while the reflection stage provides an opportunity to review changes in understanding after learning. This application aligns with [6], which explains that the cognitive conflict e-module facilitates the disclosure of prior knowledge, the presentation of phenomena that cause conceptual conflict, the discovery of concepts through activities supported by a virtual laboratory, and the review of students' understanding during the reflection stage. The distinction of this study lies in the application of the cognitive conflict model to thermodynamics material, integrated with the deep learning approach and the local wisdom of Riau in every activity.

The deep learning approach is integrated through three principles: awareness, meaningfulness, and enjoyment. The principle of awareness is applied by guiding students to identify their prior knowledge and learning objectives. The principle of meaningfulness is realized by linking thermodynamic concepts to phenomena relevant to students' daily lives. Meanwhile, the principle of enjoyment is supported through the use of interactive e-modules, illustrations, videos, and a variety of learning activities. This integration aligns with (10), which developed e-modules based on cognitive conflict and deep learning as digital teaching materials for physics instruction. This study complements that development by integrating local wisdom as a learning context. Thus, the application of cognitive conflict is not only directed toward changes in conceptual understanding but is also supported by learning experiences that encourage student engagement in understanding concepts consciously and meaningfully.

Local wisdom is integrated through the use of phenomena related to traditional food processing and the utilization of palm oil industry products in the Riau and Dumai regions. These phenomena serve as a context to connect thermodynamic concepts with community activities, enabling students to recognize the application of physics concepts in everyday life. The integration of local context into physics learning aligns with [13], which demonstrates that local wisdom can be used to explore physics concepts in community life. Additionally, [20]

developed a physics module based on local wisdom covering the topics of temperature and heat. Unlike those two studies, the e-module developed in this study uses a local wisdom context to support thermodynamics learning while linking it to the stages of cognitive conflict and the principles of deep learning. The use of this context provides an alternative way of presenting physics material that is more closely aligned with students' environments and experiences.

Expert validation results indicate that the e-module meets the criteria for highly valid in terms of content substance, visual communication, instructional design, and software utilization. Based on Aiken's V scores for these four aspects, the average validation score was 0.9282, falling into the highly valid category. These results are supported by the alignment of the content with learning objectives, the integration of stages of cognitive conflict, the application of deep learning principles, and the incorporation of local wisdom into learning activities. The validators' feedback was addressed by refining the instructional planning components, adding illustrations to the experimental steps in the worksheets, and strengthening student self-reflection. These improvements were made to clarify activity procedures and enhance the integration of instructional components. This aligns with [21], which indicates that the development of visually-based physics modules received favorable feasibility ratings from experts in media, content, and learning resources. This similarity indicates that visual presentation is a key component that must be considered in the development of physics instructional materials. Thus, the validation results demonstrate not only the content appropriateness of the e-module but also the feasibility of its instructional design and presentation.

In the one-to-one evaluation, the practicality of the e-module was assessed based on ease of use, appeal, efficiency, and benefits. The average practicality score was 93.84%, falling into the very practical category. These results indicate that students were able to understand the usage instructions, read the material, participate in learning activities, and navigate the e-module effectively. The presentation and layout of the material also helped maintain student engagement while using the product. This stage provides direct information regarding the user experience in accessing and understanding the e-module's content, so that student feedback can be used to improve sections that are still unclear before the product is used in a broader learning context. Thus, the one-to-one approach plays a role in ensuring that the product is not only suitable in terms of content but also easy for students to use. These evaluation results provide preliminary information regarding the product's use and serve as a basis for refining the e-module.

The results of the teacher practicality assessment also showed positive responses to the e-module regarding ease of use, appeal, efficiency, and benefits. The e-module received an average score of 95.93%, falling into the very practical category. These results indicate that the e-module is considered easy to use and can support the teaching of thermodynamics. The presentation of material, learning activities, worksheets, and reflections can help teachers guide students' learning activities. However, the use of the e-module needs to be adapted to the time allocation and classroom conditions so that each activity can be carried out effectively. The availability of digital devices, the stability of the internet connection, and teacher guidance also need to be considered in its implementation.

The findings of this study have implications for physics education, particularly in the presentation of material containing abstract concepts that have the potential to cause misconceptions, such as thermodynamics. The developed e-module can serve as an alternative digital teaching resource that helps teachers identify students' prior understanding, present phenomena that trigger cognitive conflict, and guide students to construct and reflect on their understanding based on scientific concepts. The integration of deep learning and local wisdom also provides opportunities for teachers to connect physics concepts with students' experiences and living environments. However, this study has limitations because the development process only covered testing for validity and practicality. The effectiveness of the e-module in remediating students' misconceptions has not been tested through pre- and post-use assessments. Therefore, the results of this study cannot yet demonstrate the extent of changes in misconceptions following instruction using the e-module.

Theoretically, this study contributes a design for an e-module that integrates the cognitive conflict model, the deep learning approach, and local wisdom into thermodynamics instruction. Practically, the product provides an alternative digital instructional resource that teachers can use to present material in a structured manner and to facilitate learning activities and student reflection on their understanding. The results of expert validation, one-to-one evaluations, and teacher practicality assessments indicate that the e-module meets the criteria for high validity and high practicality based on the instruments used. Thus, the developed e-module can be used as an alternative teaching resource in thermodynamics instruction, although effectiveness testing is still needed to determine its ability to remediate students' misconceptions.

IV. CONCLUSION

This development resulted in a cognitive conflict-based e-module integrated with a deep learning approach and Riau's local wisdom on thermodynamics using Google Sites. The e-module was developed through four stages of cognitive conflict: activation of preconceptions and misconceptions, presentation of cognitive conflict, discovery of concepts and equations, and reflection all while integrating the principles of mindfulness, meaningfulness, and enjoyment, as well as Riau's local wisdom, within the context of thermodynamics learning. Expert validation results yielded an average Aiken's V of 0.9282, classified as "highly valid." Practicality evaluation results showed an average of 93.84% from students via one-on-one evaluations and 95.93% from teachers, classified as "highly practical." Thus, the developed e-module meets the criteria of being highly valid and highly practical for use as an alternative physics teaching material on thermodynamics. However, the effectiveness of the e-module in remediating students' misconceptions has not yet been tested, so further research is still needed.

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