



Validity of a Problem-Based Learning Science E-Module Integrated with Ethnophysics to Support Science Process Skills and Critical Thinking Abilities

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Abstract

This study aimed to evaluate the validity of a Problem-Based Learning (PBL)-based science e-module integrated with the ethnophysical context of the *Perang Ketupat* tradition for teaching temperature and heat to support students' science process skills and critical thinking abilities. The study was motivated by the limited integration of Problem-Based Learning, ethnophysics, science process skills, and critical thinking within a single science e-module, as identified through a review of previous studies. This research employed the Research and Development (R&D) method using the Four-D (4D) model, consisting of the Define, Design, Develop, and Disseminate stages, but was limited to the Develop stage focusing on expert validation. The developed instructional package included the Learning Objectives Flow, teaching module, science e-module, Student Worksheets, science process skills assessment instrument, and critical thinking assessment instrument. Product validation was conducted by five purposively selected experts representing science and physics content, instructional design and Problem-Based Learning, ethnoscience, educational assessment, and language. The validation covered content, presentation, and language aspects and was analyzed using Aiken's V coefficient. The results showed that all developed products achieved valid criteria, with Aiken's V values of 0.93 for the ATP, 0.92 for the teaching module, 0.91 for the science e-module, 0.89 for the LKPD, 0.88 for the science process skills assessment instrument, and 0.89 for the critical thinking assessment instrument. These findings indicate that the developed instructional materials satisfy the required quality standards (valid) and are appropriate for subsequent practicality and effectiveness testing before wider classroom implementation.

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INTRODUCTION

Educational development in the era of the Fourth Industrial Revolution requires students to master twenty-first century competencies, including critical thinking, problem solving, communication, collaboration, creativity, and digital literacy. In science education, these competencies should be developed through meaningful learning experiences that connect scientific concepts with authentic phenomena encountered in students' daily lives. Such learning enables students not only to understand scientific concepts but also to apply scientific knowledge to solve real-world problems. Consequently, science learning requires innovative instructional materials that are contextual, technology-supported, and capable of facilitating higher-order thinking skills through student-centered learning activities [1], [2].

Despite these demands, science instruction in many schools remains predominantly teacher-centered and emphasizes conceptual transmission rather than scientific inquiry. Learning activities are still largely dependent on printed textbooks, providing students with limited opportunities to investigate scientific phenomena independently. As a result, students' science process skills (SPS), including observing, classifying, predicting, measuring, interpreting data, and communicating findings, remain at low to moderate levels because classroom learning rarely engages students in authentic scientific investigations [3], [6]. Similarly, students continue to experience difficulties in clarifying problems, evaluating evidence, drawing logical conclusions, and constructing scientific arguments, indicating that their critical thinking abilities have not yet developed optimally [4], [7].

One promising approach to overcome these challenges is the integration of ethnophysics into science learning. Ethnophysics is a branch of ethnoscience that examines scientific principles embedded within local cultural practices, allowing students to learn scientific concepts through familiar cultural phenomena. Previous studies have demonstrated that ethnophysics-based learning improves conceptual understanding, increases students' learning motivation, and creates more meaningful and contextual learning experiences [8]–[11]. Beyond conceptual understanding, ethnophysics also encourages students to interpret scientific phenomena from their surrounding environment, thereby providing opportunities to develop critical thinking through scientific analysis of local wisdom [10], [11].

One authentic ethnophysical context that has considerable potential for science learning is the Perang Ketupat tradition in Lombok, particularly the process of preparing and boiling ketupat. This cultural practice represents several essential concepts in temperature and heat, including heat transfer by conduction, convection, and radiation, heat absorption during cooking, thermal equilibrium between the boiling water and the ketupat, as well as phase changes involving water evaporation and steam formation that illustrate latent heat. Consequently, the process of boiling ketupat provides an authentic scientific phenomenon through which students can relate abstract physics concepts to observable cultural practices, making science learning more contextual and meaningful.

The effectiveness of ethnophysics-based learning can be further enhanced when integrated with the Problem-Based Learning (PBL) model. Problem-Based Learning places authentic problems at the center of the learning process and guides students through systematic inquiry involving problem identification, information gathering, investigation, data analysis, solution development, and reflection. These learning stages naturally facilitate the development of science process skills because students are actively involved in observing phenomena, formulating hypotheses, conducting investigations, interpreting evidence, and communicating findings scientifically [12], [13]. Simultaneously, each stage of inquiry requires students to analyze evidence critically, evaluate alternative explanations, formulate logical arguments, and justify decisions using scientific reasoning, thereby fostering critical thinking abilities [17], [18]. Therefore, within this integrated framework, ethnophysics functions as the contextual foundation, Problem-Based Learning serves as the pedagogical approach, science process skills represent the scientific inquiry process, and critical thinking becomes the expected learning outcome.

Recent advances in educational technology have also encouraged the development of electronic modules (e-modules) as innovative digital teaching materials. Compared with conventional printed materials, e-modules provide flexible access, multimedia integration, interactive learning activities, and greater opportunities for self-directed learning. Previous studies have reported that e-modules improve students' engagement, conceptual understanding, learning motivation, and independent learning skills [5], [19], [20]. Nevertheless, most existing e-modules focus primarily on digital presentation and interactivity without simultaneously integrating Problem-Based Learning and ethnophysics within a single instructional product. Consequently, the potential of combining contextual cultural learning with inquiry-based pedagogy has not yet been fully explored.

To establish the research gap systematically, a focused literature review was conducted on studies published between 2021 and 2025 using the references relevant to science e-modules, Problem-Based Learning, ethnophysics, science process skills, and critical thinking that form the basis of this study [5], [8]–[13], [16], [19], [20], [24], [27], [30]. The reviewed studies indicate three important gaps. First, previous studies predominantly developed either ethnophysics-based teaching materials

[8]–[11] or PBL-based e-modules [13], [16], [19], [20], while only limited studies integrated both approaches simultaneously into a comprehensive science e-module. Second, most previous developments primarily targeted conceptual understanding, scientific literacy, or twenty-first century skills in general, whereas relatively few studies simultaneously emphasized the development of both science process skills and critical thinking abilities through a single instructional product [16], [24], [25], [27], [30]. Third, despite the richness of Indonesian local culture, no previous study has specifically utilized the Perang Ketupat tradition and the ketupat boiling process as an ethnophysical context for learning the concepts of temperature and heat.

In addition to identifying the research gap, previous validation studies also provide an important benchmark for evaluating the quality of instructional materials. Earlier studies reported that science e-modules and ethnosience-based instructional materials generally achieved Aiken's V values ranging from approximately 0.88 to above 0.90, indicating that these products satisfied acceptable validity standards before classroom implementation [16], [19], [20], [24], [27]. These findings establish an important reference for the present study, which aims to develop a more comprehensive instructional package by integrating Problem-Based Learning, ethnophysics, science process skills, and critical thinking within a single learning product while achieving a comparable or higher level of validity through expert evaluation.

Based on the theoretical and empirical arguments presented above, this study proposes an integrated conceptual framework in which the Perang Ketupat ethnophysical context serves as an authentic problem that is investigated through the stages of Problem-Based Learning. Throughout the inquiry process, students practice essential science process skills, including observing, predicting, measuring, interpreting, and communicating scientific findings. These scientific activities subsequently facilitate students' critical thinking by requiring them to analyze evidence, evaluate alternative explanations, formulate scientific arguments, and draw reasoned conclusions. Accordingly, the integration of ethnophysics and Problem-Based Learning is theoretically expected to provide meaningful science learning experiences while simultaneously strengthening science process skills and critical thinking abilities.

Therefore, this study aims to analyze the validity of a Problem-Based Learning-based science e-module integrated with ethnophysics for teaching temperature and heat concepts through the Perang Ketupat tradition. The developed instructional package includes the learning objective flow, teaching module, science e-module, student worksheets, science process skills assessment instrument, and critical thinking assessment instrument. Product validity was evaluated using Aiken's V coefficient to determine whether all instructional materials satisfy the required standards of content, presentation, language, and graphical design before proceeding to classroom implementation.

METHODE

This study employed a Research and Development (R&D) approach using the Four-D (4D) development model proposed by Thiagarajan et al., which consists of four stages: Define, Design, Develop, and Disseminate [14]. However, this study was limited to the Develop stage, focusing on expert validation of the developed instructional products before classroom implementation. The products developed comprised a Learning Objectives Flow (ATP), a teaching module, a science e-module based on Problem-Based Learning (PBL) integrated with ethnophysics, Student Worksheets (LKPD), a science process skills assessment instrument, and a critical thinking assessment instrument.

The validation process involved five expert validators selected purposively based on their expertise and experience in science education and instructional material development. The validators consisted of two experts in science/physics content, two experts in science education, Problem-Based Learning (PBL), instructional design, and ethnosience, and one expert in educational assessment and language. This distribution of expertise ensured that the three validation aspects content, presentation, and language were comprehensively evaluated by experts in their respective fields.

The expert validation covered three major aspects: content validity, presentation validity, and language validity. Content validity examined the appropriateness of scientific concepts, curriculum alignment, integration of ethnophysics, implementation of Problem-Based Learning syntax, and

consistency with indicators of science process skills and critical thinking abilities. Presentation validity assessed the organization of learning materials, instructional sequence, graphical appearance, multimedia components, and the effectiveness of learning activities in facilitating student engagement. Language validity evaluated readability, clarity of instructions, grammatical accuracy, consistency of terminology, and the suitability of language for junior secondary school students.

Each validator assessed every instructional product using a five-point Likert scale ranging from 1 (very inappropriate) to 5 (very appropriate). The obtained scores were analyzed using Aiken's V coefficient to determine the content validity of each instructional product [16]. Aiken's V was selected because it is widely used to quantify the degree of agreement among experts regarding the relevance of each assessment criterion.

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

Where V represents the validity coefficient, $s = r - l_0$, r is the score assigned by each validator, l_0 is the lowest score on the rating scale, n is the number of validators, and c is the highest score on the rating scale.

The resulting Aiken's V coefficients were subsequently interpreted according to the established validity criteria [15]. Higher Aiken's V values indicate stronger agreement among experts regarding the validity of the developed instructional materials. The validity categories used in this study are presented in Table 1.

Table 1. Aiken's V Validity Coefficient (Aiken, 1985)

Value Range	Validation Level
$V < 0.75$	Invalid
$V \geq 0.75$	Valid

RESULT AND DISCUSSION

Product validation was conducted by five expert validators. The evaluation covered six instructional materials: the Learning Objective Flowchart (ATP), teaching modules, e-modules, worksheets, science process skills assessment instruments, and critical thinking abilities assessment instruments. Validity analysis was performed using Aiken's V coefficient, focusing on three evaluation aspects: content, presentation, and language.

Table 2. Validity Results of the Instructional Materials

Instrument	Aiken's V	Category
ATP	0,93	Valid
Teaching Module	0,92	Valid
E-Module	0,91	Valid
LKPD	0,89	Valid
Science Process Skills Test	0,88	Valid
Critical Thinking Abilities Test	0,89	Valid

Based on Table 2, all instructional materials received validity scores in the range of 0.88–0.93, falling into the “valid” category. The highest validity score was achieved by the ATP at 0.93, followed by the teaching module at 0.92, and the e-module at 0.91. Meanwhile, the worksheets scored 0.89, the critical thinking test scored 0.89, and the science process skills test scored 0.88. These results indicate that all teaching materials meet the feasibility criteria and can therefore be used in the implementation phase after being refined according to the validators' suggestions.

In addition to assigning evaluation scores, the validators also provided several recommendations for improvements to each developed learning module. For the ATP, the validators suggested refining the formulation of learning objectives using the ABCD format (audience, behavior, condition, and degree) and adjusting the indicators for science process skills and critical thinking abilities. In the teaching modules, revisions were made to the time allocation, teacher and student activities, and the identification of activities that facilitate science process skills and critical thinking

abilities. Revisions to the e-modules included improvements to illustrations, the presentation of material, consistency in the ethno-physics context, and the addition of image sources. The worksheets were revised by adapting ethno-physics-based problems and adjusting their placement within each learning activity. Meanwhile, the assessment instruments for science process skills and critical thinking abilities were revised in terms of item construction, the use of standard language, the development of contextual stimuli, and the alignment of items with the indicators being measured. All of these suggestions have been incorporated, resulting in a better final product.

Validity of the Learning Objectives Sequence (ATP)

The validation of the Learning Objectives Sequence (ATP) was conducted by five expert validators to assess aspects of content, presentation, and language. The results of the ATP validation are presented in Table 3.

Table 3. Validation Results of the Learning Objective Flow (ATP)

Assessed Aspects	Aiken's V	Category
Content	0,94	Valid
Presentation	0,92	Valid
Language	0,93	Valid
Average	0,93	Valid

The validation results show that the Learning Objectives Flow achieved an Aiken's V score of 0.93, placing it in the "valid" category. This score is the highest compared to other instruments, indicating that the ATP meets the criteria for content, presentation, and language. The high validity score indicates that the learning objectives have been formulated systematically, are aligned with the Learning Outcomes of the Merdeka Curriculum, and are integrated with the indicators of science process skills and critical thinking abilities that are the focus of this study.

These findings indicate that the ATP has served as a guideline for designing structured learning experiences focused on students' competency attainment. The alignment between learning outcomes, learning objectives, achievement indicators, and learning activities resulted in a high level of agreement among validators regarding the quality of the developed ATP. Learning objectives are the cornerstone of instructional design because they determine the selection of content, instructional strategies, learning activities, and assessment tools. Therefore, learning objectives must be formulated in a way that is specific, measurable, and aligned with the competencies to be achieved.

The results of this study are consistent that instructional materials achieve high validity when learning objectives are systematically formulated and are strongly aligned with learning outcomes, instructional strategies, and assessment instruments. Consequently, a valid ATP provides clear direction for implementing Problem-Based Learning (PBL), ensuring that all developed instructional materials are well-integrated.

Validity of the Instructional Modules

The instructional modules developed were validated based on content, presentation, and language. A summary of the validation results is presented in Table 4.

Table 4. Validation Results of the Teaching Module

Assessed Aspects	Aiken's V	Category
Content	0,93	Valid
Presentation	0,91	Valid
Language	0,92	Valid
Average	0,92	Valid

The instructional module received an Aiken's V score of 0.92, falling into the "valid" category. These results indicate that the instructional module meets the validity criteria in terms of content, presentation, and language. The validator assessed that the Problem-Based Learning (PBL) framework had been systematically applied to every learning activity, from problem orientation to problem-

solving evaluation. The high validity score indicates that the teaching module effectively integrates learning objectives, teacher activities, student activities, and assessment into a cohesive, unified learning experience. The systematic design of the teaching module facilitates teachers in implementing student-centered learning.

According to Arends, the effective implementation of Problem-Based Learning (PBL) requires systematic instructional planning so that each phase of learning can facilitate the process of inquiry and problem-solving. Furthermore, the Ministry of Education, Culture, Research, and Technology emphasizes that instructional modules in the Merdeka Curriculum must integrate learning objectives, learning activities, assessment, and differentiated instruction [17], [18].

These findings support the research, which shows that PBL-based teaching modules have a high level of validity because they guide teachers in implementing active, student-centered learning. The implication of these results is that valid teaching modules can improve the consistency of PBL implementation in the classroom, ensuring that the learning process proceeds in accordance with the designed objectives [13].

Validity of the E-Module

The science e-module based on Problem-Based Learning (PBL) and integrated with ethnophysics was validated in terms of content, presentation, and language. The validation results are presented in Table 3.

Table 5. Validation Results of the Science E-Module

Assessed Aspects	Aiken's V	Category
Content	0,92	Valid
Presentation	0,91	Valid
Language	0,90	Valid
Average	0,91	Valid

The e-module received an Aiken's V score of 0.91, falling into the "valid" category. These results indicate that the developed e-module meets the criteria for content, presentation, and language. The validators assessed that the material on temperature and heat was organized systematically, used language that was easy to understand, and integrated local culture by using the Ketupat War as a learning context.

The high validity score indicates that the e-module not only serves as a medium for conveying information but is also capable of facilitating students in building knowledge through Problem-Based Learning (PBL) activities [5], [19], [20]. The presentation of local cultural phenomena brings science concepts closer to students' experiences, thereby making learning more meaningful. According to Mayer (2021), digital instructional materials designed based on multimedia principles can support conceptual understanding when information is presented in an integrated manner through text, images, and learning activities. Furthermore, contextual learning suggests that scientific concepts are easier to understand when linked to real-life situations relevant to students' lives [21], [22].

The results of this study are consistent with the research by Logan et al. (2021), which reported that Problem-Based Learning (PBL)-based e-modules achieved high validity because they were able to improve the quality of material presentation, interactivity, and student engagement in the learning process. Consequently, valid e-modules have great potential to be used as digital teaching materials that support the implementation of the Merdeka Curriculum while developing 21st-century skills through problem-based learning [20], [23].

Validity of Student Worksheets (LKPD)

The LKPDs were validated to determine the alignment of learning activities with the Problem-Based Learning (PBL) framework. The validation results are presented in Table 6.

Table 6. Validation Results of the LKPD

Assessed Aspects	Aiken's V	Category
Content	0,90	Valid
Presentation	0,89	Valid
Language	0,88	Valid
Average	0,89	Valid

The Student Worksheet (LKPD) received an Aiken's V score of 0.89, which falls into the "valid" category. This score indicates that the LKPD meets the criteria for content, presentation, and language, making it suitable for use in instruction. The validator assessed that the activities in the LKPD align with the Problem-Based Learning (PBL) framework and are capable of facilitating students in conducting scientific activities, such as observing, collecting data, analyzing results, and drawing conclusions. Although the language aspect received a slightly lower score compared to the other aspects, the difference is relatively small and does not affect the overall suitability of the product.

A good worksheet must be able to guide students in discovering concepts through systematic activities, involve higher-order thinking processes, and provide opportunities for students to construct knowledge independently. These results support the research, which shows that PBL-based worksheets generally achieve high validity because learning activities designed according to problem-solving stages are able to increase student engagement. Consequently, valid worksheets can serve as an effective tool for training science process skills while developing students' critical thinking abilities through structured learning activities [1], [16], [24].

Validity of the Science Process Skills Test

The science process skills test instrument was validated based on indicator alignment, item construction, and language use. The validation results are shown in Table 7.

Table 7. Validation Results of the Science Process Skills Test

Assessed Aspects	Aiken's V	Category
Content	0,89	Valid
Presentation	0,87	Valid
Language	0,88	Valid
Average	0,88	Valid

The science process skills test instrument obtained an Aiken's V value of 0.88, which falls within the "valid" category. Although this value was the lowest among the other instruments, it still exceeded the minimum validity threshold, making the instrument suitable for measuring students' science process skills.

The slightly lower validity score indicates that the validators paid closer attention to the alignment of each test item with the science process skill indicators, namely observing, classifying, predicting, measuring, inferring, and communicating. Developing such an instrument does indeed require a high degree of precision because each item must truly be able to measure scientific processes, not merely conceptual mastery. Science process skills instruments must be designed based on clear indicators so that they can measure students' ability to engage in authentic scientific processes. Furthermore, Brookhart emphasizes that instruments for higher-order thinking require contextual stimuli and detailed scoring rubrics to ensure that construct validity is maintained [25], [26].

These findings are consistent with the study by Fadilah et al. (2023), which showed that the validity of science process skills instruments is generally slightly lower than that of instructional materials because the development of indicators and assessment rubrics requires a higher degree of precision. Consequently, valid instruments can provide accurate information regarding students' mastery of science process skills and are therefore suitable for use as evaluation tools in research [27].

Validity of the Critical Thinking Abilities Test

The critical thinking abilities instrument was validated based on content, construct, and language aspects. The validation results are presented in Table 8.

Table 8. Validation Results for the Critical Thinking Abilities Test

Assessed Aspects	Aiken's V	Category
Content	0,90	Valid
Presentation	0,88	Valid
Language	0,89	Valid
Average	0,89	Valid

The critical thinking abilities test instrument obtained an Aiken's V value of 0.89, which falls within the "valid" category. These results indicate that all test items successfully represented the critical thinking skill indicators used in the study, namely basic clarification, basic decision-making, inference, further explanation, and reasoning and integration.

The validators assessed that each item was designed using contextual stimuli drawn from ethnophysical phenomena, thereby requiring students to analyze information, provide scientific reasoning, draw conclusions, and integrate various concepts to solve problems. The high validity score indicates that the instrument demonstrates good alignment between the measurement objectives, indicators, and item construction. Critical thinking is a reflective and rational thought process oriented toward decision-making based on justifiable reasoning. Therefore, a critical thinking instrument must be able to measure students' ability to present arguments, evaluate evidence, draw inferences, and integrate various pieces of information [28].

The results of this study align with the researches which reported that critical thinking assessment instruments achieve high validity when developed based on clear critical thinking indicators and utilize contextual problem-based stimuli. Consequently, instruments that meet validity criteria can be used to measure students' critical thinking abilities more comprehensively and support the evaluation of the effectiveness of Problem-Based Learning (PBL)-based instruction [29], [30].

Overall, all of the learning materials developed achieved validity scores ranging from 0.88 to 0.93, falling into the "valid" category, indicating that the ATP, teaching modules, e-modules, worksheets, science process skills tests, and critical thinking abilities tests met the criteria for content, presentation, and language. The differences in validity scores among the instruments were relatively small, indicating that all materials are of balanced quality and mutually supportive as a unified set of Problem-Based Learning (PBL)-based instructional materials integrated with ethnophysics. Thus, the developed products are suitable for use in the implementation phase to test their practicality and effectiveness in improving students' science process skills and critical thinking abilities.

CONCLUSION

The results of expert validation indicate that the developed instructional package, consisting of the Learning Objectives Flow, teaching module, science e-module, Student Worksheets, science process skills assessment instrument, and critical thinking assessment instrument, achieved Aiken's V values ranging from 0.88 to 0.93, indicating that all products fall within the valid category. Specifically, the ATP obtained an Aiken's V value of 0.93, the teaching module 0.92, the science e-module 0.91, the LKPD 0.89, the science process skills assessment instrument 0.88, and the critical thinking assessment instrument 0.89. These findings demonstrate that the developed instructional materials satisfy the required standards for content, presentation, and language, indicating their suitability for use in subsequent stages of development after incorporating the experts' recommendations.

As this study was limited to the Develop stage of the 4D model, further research is recommended to continue the Disseminate stage through field implementation. Future studies should conduct practicality testing involving science teachers and Grade VII junior secondary school students from at least two schools to evaluate the usability and implementation of the developed e-module. Furthermore, effectiveness testing using a quasi-experimental design is recommended to examine the

impact of the e-module on students' science process skills and critical thinking abilities before wider dissemination.

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