JPPIPA 11(12) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Validity and Practicality of the Physics E-Module on Integrated Thermodynamics Material on Volcanic Eruptions Based on the ICARE Model to Improve Students' Creative Thinking Skills

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Received: October 03, 2025
Revised: November 14, 2025
Accepted: December 25, 2025
Published: December 31, 2025

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DOI: 10.29303/jppipa.v11i12.13332

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Abstract: This study aims to determine the validity and practicality of an integrated physics E-Module on thermodynamics material related to volcanic eruptions based on the ICARE (Introduction, Connection, Application, Reflection, and Extension) learning model to improve students' creative thinking skills. The research was conducted using the ADDIE development model, focusing on the stages of validation and practicality testing. The validity test involved five validators consisting of lecturers and teachers, while the practicality test was conducted with physics teachers and eleventh-grade students. The results showed that the developed E-Module obtained an average Aiken's V score of 0.88, categorized as valid. The practicality test results indicated that the E-Module was very practical, with an average score of 95.33% of teachers and 88.67% of students. These findings demonstrate that the ICARE-based E-Module is valid and highly practical for use in physics learning. Moreover, the integration of thermodynamics concepts with volcanic eruption phenomena provides contextual learning experiences that support the development of students' creative thinking skills.

Keywords: Creative thinking skills; E-Module; ICARE model; Thermodynamics; Volcanic eruptions

Introduction

Education plays a central role in shaping high-quality and competitive human resources. Through education, individuals are trained to think critically, creatively, and adaptively in response to the dynamics of modern life. Consequently, education has become one of the main indicators of a nation's progress. Developed countries continuously strive to improve the quality of education to produce competent and innovative generations. One of the Indonesian government's strategic efforts to enhance educational quality is through curriculum reform (Suryadi et al., 2019; Dewi, 2021).

The *Merdeka Curriculum* was introduced as a refinement of the previous curriculum, emphasizing flexibility, student-centered learning, and the development of 21st-century competencies. This transformation is based on a comprehensive evaluation of the previous curriculum's implementation and a critical analysis of future global educational challenges (Azmi et al., 2023; Sappaile et al., 2024). One of its main focuses is the development of the *Profil Pelajar Pancasila* (Pancasila Student Profile), which highlights six essential character dimensions, including creative thinking skills (Nurhayati et al., 2022; Putra et al., 2025). However, a preliminary study conducted in a public school in Pesisir Selatan Regency revealed that students' creative thinking skills remain low, with an average score of only 46%, categorized as poor. This finding indicates the urgent need for systematic efforts to enhance students' creative thinking abilities, particularly in science and physics learning.

Creative thinking skills are rarely fostered in physics classrooms, as teachers often focus primarily on completing the curriculum and delivering all required materials. Consequently, students become passive and

How to Cite:
Arlim, M., & Fauzi, A. (2025). Validity and Practicality of the Physics E-Module on Integrated Thermodynamics Material on Volcanic Eruptions Based on the ICARE Model to Improve Students' Creative Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *11*(12), 521-527. https://doi.org/10.29303/jppipa.v11i12.13332

less involved in conceptual understanding and scientific inquiry (Rahardjanto et al., 2019; Rizal et al., 2020). Physics, however, is a field rich with natural phenomena that can be used to cultivate creativity and divergent thinking. One of the physics topics that holds significant potential for developing creative thinking is thermodynamics, as it closely relates to real-world energy transformations and natural processes (Haddad, 2017; Cueto & Chinesta, 2023). Connecting abstract physics concepts with real phenomena can make learning more meaningful and contextually relevant.

One phenomenon that can be effectively linked to thermodynamics is volcanic eruptions. The eruption of Mount Marapi in West Sumatra on December 3, 2023, which claimed 23 lives, serves as a reminder of the importance of integrating disaster education into school learning. With volcanic activity remaining high as of January 2024, students need to understand such events not only geographically but also scientifically through physics principles. Integrating thermodynamics with the context of volcanic eruptions enables students to recognize real applications of physics principles, thus enhancing engagement and creative thinking (Saregar et al., 2025). Therefore, innovative teaching materials are required to bridge abstract physics concepts with concrete real-world contexts.

The rapid advancement of digital technology presents great opportunities for developing interactive and adaptive learning media tailored to students' needs. E-Modules, as a modern evolution of conventional modules, offer interactive multimedia features such as animations, simulations, and instructional videos that make learning more engaging (Yulando et al., 2019; Cahyanto & Afifulloh, 2020; Habibi et al., 2022). Electronic modules also promote flexibility and self-paced learning, allowing students to access materials anytime and anywhere. However, to ensure meaningful learning outcomes, the development of E-Modules must be grounded in a pedagogically sound learning model that promotes active and reflective engagement (Manggala et al., 2024; Chairad et al., 2025; Holisoh et al., 2023).

The ICARE model (Introduction, Connection, Application, Reflection, and Extension) is an ideal framework for developing interactive E-Modules in physics learning. This model emphasizes active student involvement in constructing concepts through scientific and reflective activities (Siahaan et al., 2020; Sa'diyah et al., 2021; Latifah et al., 2022). During the *Connection* and *Application* stages, learners relate physics concepts to real-life phenomena and apply them in new contexts, fostering originality and creative thinking (Beck & Perkins, 2016). The *Reflection* and *Extension* stages further encourage students to evaluate and expand their conceptual understanding (Sa'diyah et al., 2021; Fauzi & Inayati, 2023; Jolly, 2024). Therefore, integrating the ICARE model into a physics E-Module has strong potential to continuously enhance students' creative thinking abilities.

To ensure effective implementation, the developed E-Module must demonstrate high levels of validity and practicality. Validity includes aspects such as content accuracy, readability, and the meaningfulness of materials for learners (Erita, 2022; Halik et al., 2024). Meanwhile, practicality refers to the ease of use for both teachers and students, as well as the module's effectiveness in supporting learning objectives aligned with the *Merdeka Curriculum* (Razi, 2024). Therefore, this study aims to examine the validity and practicality of an ICARE-based physics E-Module integrated with volcanic eruption contexts to enhance students' creative thinking skills. The module's validity was assessed by experts in physics education, while its practicality was evaluated based on teachers' and students' responses regarding usability and effectiveness. The results of this study are expected to contribute significantly to the development of innovative and effective learning materials that promote active, creative, and contextual learning in physics.

Method

This study employed a research and development (R&D) design using the ADDIE model, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation (Branch & Varank, 2009). This model was chosen because it provides a systematic framework for designing, developing, and evaluating instructional products in a continuous and iterative manner. However, this research specifically focused on two stages validity testing and practicality testing of the developed ICARE-based physics E-Module integrated with volcanic eruption phenomena.

The validity test was carried out by five validators, consisting of three university lecturers and two physics teachers with prior experience in similar product development. The validation process included assessments of content accuracy, presentation, language, and graphical design. Meanwhile, the practicality test involved one physics teacher and students from class XI. F2 as respondents to evaluate the usability, effectiveness, and attractiveness of the E-Module in the learning process.

Data were collected using validity and practicality questionnaires with a Likert scale as follows.

Table 1. Likert Scale of Assessment

Scale	Description
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

After respondents completed the Likert-scale questionnaire, product validity was calculated using the following formula.

$$V = \frac{\sum S}{n(C-1)} \quad (1)$$

where:
$S = r - l_o$,
r= rating given by the validator,
l_o= lowest possible score,
C= highest possible score,
n= total number of validators.

This formula follows the product validity analysis proposed by Azwar (2015). The level of product validity was then interpreted using the following criteria.

Table 2. Validity Criteria (Azwar, 2015)

Category	Criteria
≥ 0.6	Valid
≤ 0.6	Invalid

After the validity test, the next stage was the practicality test, which aimed to determine the ease of use and effectiveness of the E-Module in classroom implementation. The practicality instrument was administered to both teachers and students, and the results were analyzed using the following formula (Riduwan, 2010).

$$Practicality\ Value = \frac{Obtained\ Score}{Ideal\ Maximum\ Score}\ x\ 100\% \quad (2)$$

The practicality level of the E-Module was then interpreted using the criteria presented in Table 3.

Table 3. Practical Criteria (Azwar, 2015)

No	Achievement Level	Category
1	81-100	Very Practical
2	61-80	Practical
3	41-60	Fairly Practical
4	21-40	Less Practical
5	0-20	Not Practical

This approach enabled the researchers to obtain an objective evaluation of the product's quality, both in terms of content and its practical application in real classroom settings. The results of the validity and practicality tests serve as a foundation for determining the feasibility of the ICARE-based physics E-Module for use in thermodynamics learning integrated with volcanic eruption contexts.

Result and Discussion

Result

Based on the problems identified in the field, the ICARE-based integrated physics E-Module on thermodynamics and volcanic eruptions serves as a solution to improve students' creative thinking skills. The developed E-Module was designed to integrate thermodynamics concepts with volcanic eruption phenomena, creating contextual and meaningful learning experiences that stimulate students' creative thinking. Figure 1 presents a portion of the developed E-Module design.

Figure 1. Excerpt of the ICARE-Based Physics E-Module

After the E-Module was developed, the next step was to conduct validity and practicality tests to ensure the product's feasibility before its classroom implementation. The results of these two tests served as basis for determining whether the E-Module is suitable for use as an innovative teaching material in physics learning.

Validity Test Results

The validation process was conducted by five experts, three university lecturers and two experienced physics teachers. The evaluation employed a validation questionnaire designed to assess four main aspects: content substance, instructional design, visual presentation, and software utilization. Validators also provided comments and suggestions for improvement, as summarized in Table 4. After revising the E-Module based on the validators' feedback, the validation results were analyzed. The overall expert validation scores are shown in Table 5.

Table 4. Comments and Suggestions from Validators

Validator	Comments and Suggestions	Follow-Up
US	Add image sources in the E-Module.	Revised
EM	Every image and video must be Accompanied by a reference	Revised
	The learning outcomes must be written in full	Revised
NA	Writing not in accordance with EYD (Indonesian Grammar).	Revised
	Improve sentences in the volcanic eruption mitigation section.	Revised
	Add the word "material" on the E-Module cover.	Revised
RH	Arrange learning objectives using the ABCD formula.	Revised
IZ	Add references/sources for cited images.	Revised

Table 5. Expert Validation Results

No	Aspect	Score	Criteria
1	Material substance	0.93	Valid
2	Instructional design	0.96	Valid
3	Visual presentation	0.95	Valid
4	Software utilization	0.70	Valid
	Average	0.88	Valid

The table shows that the developed E-Module obtained an average Aiken's V coefficient of 0.88, categorized as valid. This indicates that the ICARE-based integrated E-Module for high school thermodynamics is appropriate for classroom implementation.

A highly valid E-Module contributes to more effective learning by presenting material systematically and comprehensibly (Rojikin et al., 2022; Ananda & Usmeldi, 2023). Well-validated digital teaching materials have also been shown to enhance students' learning motivation and active participation during instruction (Rahayu & Sukardi, 2021). Thus, the validation results confirm that the ICARE-based E-Module possesses strong content accuracy and visual quality, making it an innovative instructional medium capable of supporting the development of students' creative thinking skills.

Practical Test Results

The purpose of this stage was to determine the practicality of the E-Module when used by teachers and students in physics learning. The practicality test was carried out with one physics teacher and 25 students from Class XI. F2 of SMAN 1 Painan, to assess how effectively the E-Module supports the learning process and enhances students' creative thinking.

Teacher Response Practicality

Teacher practicality data were obtained through a teacher response questionnaire, and the results are shown in Table 6.

Table 6. Teacher Response Practicality Results

No	Component	Percentage (%)	Category
1	Ease of use	97	Very Practical
2	Learning time efficiency	93	Very Practical
3	Usefulness	96	Very Practical
	Average	95.33	Very Practical

The table shows that the average teacher practicality score for the E-Module was 95.33%, categorized as very practical. This suggests that the ICARE-based physics E-Module for Grade XI is highly practical for classroom use.

Student Response Practicality

Student practicality testing was conducted with 25 students from Class XI. F2 using the same evaluation instrument. The results are presented in Table 7.

Table 7. Student Response Practicality Results

No	Component	Percentage (%)	Category
1	Ease of use	89	Very Practical
2	Learning time efficiency	91	Very Practical
3	Usefulness	86	Very Practical
	Average	88.67	Very Practical

The average practicality score based on student responses was 88.67%, which also falls into the very practical category. This indicates that the ICARE-based physics E-Module is easy to use, engaging, and effective in supporting learning.

Discussion

Based on the data analysis results, the physics E-Module based on the ICARE model demonstrated a very high level of validity and practicality from both teachers' and students' perspectives. These findings indicate that the developed product not only meets the standards of content accuracy, language clarity, and visual presentation but is also easy to use and effective in supporting classroom learning. The average validity score of 0.88 shows that each component of the E-Module aligns with the principles of quality learning material development accuracy of concepts, alignment between content and learning objectives, and coherence of content with visual design (Rojikin et al., 2022; Ananda & Usmeldi, 2023). A valid E-Module ensures that the information received by students is reliable and well understood, thus making the learning process more structured and meaningful.

The practicality test results, categorized as *very practical* by both teachers and students, confirm that this E-Module can be easily operated without requiring any specific technical training. The high level of practicality also implies that the media enhances time efficiency and assists teachers in presenting abstract physics concepts more concretely and engagingly. This is consistent with findings from Holisoh et al. (2025) and Kumar et al. (2024), who revealed that interactive E-Modules can improve concept comprehension and teaching effectiveness in the classroom.

From the students' perspective, the ICARE-based E-Module provides an active and constructive learning experience. Through the *Introduction* and *Connection* stages, learners are guided to relate thermodynamics concepts to real-world phenomena such as volcanic eruptions (Asri et al., 2024; Suartama et al., 2022; Sastradiharja, 2010). This process stimulates divergent thinking and encourages the generation of original ideas. Furthermore, during the *Application* and *Reflection* stages, students are given opportunities to apply concepts in new contexts and reflect on their cognitive processes, fostering metacognitive awareness that strengthens creative thinking skills (Beck & Perkins, 2016; Sa'diyah et al., 2021). Thus, the application of the ICARE model not only enhances conceptual understanding but also promotes higher order thinking skills (HOTS), which are essential in the *Merdeka Curriculum*.

In addition, this research reinforces the idea that integrating real-world natural phenomena, such as volcanic eruptions, into physics learning can create a more contextual and meaningful learning environment. The inclusion of disaster-related contexts makes thermodynamics more relevant to daily life and provides tangible meaning for students. This finding is consistent with constructivist theory, which posits that learners actively construct knowledge through direct experience and reflection on observed phenomena (Sutton & Kaufmann, 2018). Furthermore, contextual integration contributes to developing scientific awareness and social empathy toward environmental and disaster-related issues.

Pedagogically, the ICARE-based E-Module supports 21st-century learning approaches that emphasize collaboration, communication, creativity, and critical thinking (the 4C skills). Students are not merely passive recipients of knowledge; instead, they actively interact with the content through simulations, visualizations, and reflective activities provided within the E-Module. This is supported by Kusumantoro et al. (2022) and Tumiar et al. (2025), who reported that practical and interactive E-Modules can enhance learning independence and active participation throughout the learning process.

Therefore, it can be concluded that the physics E-Module based on the ICARE model is not only valid in terms of content and design but also highly practical and effective in enhancing meaningful learning experiences (Ananda & Usmeldi, 2023). This E-Module serves not only as an instructional medium but also as a tool for developing students' creative and reflective thinking skills in a sustainable way. The findings imply that the development of ICARE-based learning materials can serve as an innovative teaching strategy aligned with the *Merdeka Curriculum* and the demands of 21st-century education.

Conclusion

Based on the results of the research conducted, it can be concluded that the ICARE-based integrated physics E-Module on thermodynamics and volcanic eruptions is declared valid and highly practical for use in learning activities. The validity test results indicate that the E-Module possesses a high level of feasibility in terms of content, presentation, language, and visual design. Meanwhile, the practicality test results show that the E-Module is easy to use by both teachers and students and effectively supports a more meaningful learning process. Furthermore, this E-Module has the potential to enhance students' creative thinking skills, as it is designed using the ICARE learning model and integrates physics concepts with the contextual phenomenon of volcanic eruptions. Therefore, the ICARE-based E-Module can serve as an innovative teaching alternative aligned with the Merdeka Curriculum and the demands of 21st-century learning.

Acknowledgments
The authors would like to express their gratitude to all parties who have contributed to the completion of this research, allowing it to be successfully carried out. Special thanks are also extended to all the authors whose works have been cited in this paper.

Author Contributions
All authors contributed equally to the writing and development of this article.

Funding
This research did not receive any external funding.

Conflicts of Interest
The authors declare that there is no conflict of interest in the preparation and publication of this article.

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