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# Development and Validation of Multi-Methods Discovery Based Physics Learning Devices to Enhance Critical Thinking in Senior High School Students

**Muliadi Said**
Doctoral Program in Education, Makassar State University,
Bonto Langkasa Street, Makassar, South Sulawesi 90222, Indonesia

**Helmi Abdullah***
Physics Education Study Program, Makassar State University,
Mallengkeri Raya Street No. 44, Makassar, South Sulawesi 90224, Indonesia
[**Corresponding author*]

**Muhammad Arsyad**
Physics Study Program, Makassar State University,
Mallengkeri Raya Street No. 44, Makassar, South Sulawesi 90224, Indonesia

**Erma Suryani Sahabuddin**
Elementary School Teacher Education Study Program, Makassar State University,
Bonto Langkasa Street, Makassar, South Sulawesi 90222, Indonesia

**Abdullahpandang**
Head of Doctoral Program in Educational Sciences, Makassar State University,
Bonto Langkasa Street, Makassar, South Sulawesi 90222, Indonesia

**Abstract**
The development of critical thinking skills remains a significant challenge in senior high school physics education. Innovative learning approaches based on multi-method discovery strategies hold promise for enhancing students' conceptual understanding and cognitive abilities more effectively. This study aimed to develop and validate physics learning materials grounded in a multi-method discovery framework to improve critical thinking skills among high school students. A descriptive research approach was utilized to assess the feasibility and validity of the instructional materials, which encompassed teaching modules, lesson plans, student worksheets, and instructional media. Validation was conducted by three experts specializing in physics education, instructional technology, and multimedia learning, employing expert validation sheets and quantitative analysis through Aiken's V coefficient. The results indicated that all components of the learning materials attained Aiken's V values above 0.77, classifying them as valid and suitable for implementation with minor revisions. Constructive feedback from the validators informed the refinement process to ensure alignment with discovery learning principles and the current curriculum standards. This study provides valuable contributions to the creation of interactive and innovative physics learning tools that foster critical thinking skills essential for 21st-century education.

**Keywords**
physics learning devices, multi-methods discovery, critical thinking skills, senior high school education

## INTRODUCTION

Comprehensive physics education requires a balance between mastery of theoretical concepts and practical competencies. One of the essential fundamental skills in this context is the accurate and effective use of measuring instruments, such as vernier calipers, micrometers, stopwatches, and multimeters. Mastery of these tools not only facilitates a deeper understanding of scientific concepts but also fosters scientific attitudes, precision, and critical thinking skills among students. Moreover, involving students in direct measurement activities promotes inquiry-based learning and enhances their ability to connect theoretical concepts with real-world phenomena. Therefore, integrating the development of measurement skills into physics instruction is crucial for cultivating scientifically literate individuals who are capable of problem-solving and reasoning based on empirical evidence (Saklíressy et al., 2021). Practice-based learning has also been shown to significantly improve essential scientific skills, including careful observation, accurate data interpretation, and sound decision-making. These competencies are vital for developing a scientific mindset and encouraging active student engagement in the scientific inquiry process (Suryadi et al., 2021). Research findings provide new insights into the development of learning strategies that can cultivate students with stronger critical thinking skills, which are relevant for implementation at the senior high school level as part of preparing students to face the challenges of the 21st century (Erdogan, 2019). From a learning perspective, physics plays a role in training students to conduct simple investigations of natural phenomena. Students learn to identify problems, formulate hypotheses, design and perform experiments, collect and analyze experimental data, draw conclusions, and communicate results both orally and in writing. Furthermore, physics education trains scientific reasoning, critical thinking, and problem-solving skills. At the senior high school level, physics is taught as a separate subject for two main reasons. First, a correct and profound understanding of physics is useful for solving everyday life problems. Second, a strong understanding of physics serves as a bridge to success in higher education, particularly in foundational science disciplines as well as in engineering and technology fields (BSKAP, 2022). According to the OECD PISA report (PISA 2022), the critical thinking abilities of Indonesian students, as reflected in reading, mathematics, and science literacy, are significantly below the OECD average. In 2022, Indonesia's average scores were 359 in reading, 366 in mathematics, and 383 in science—well below the OECD averages of 476, 472, and 485, respectively. Only 18% of Indonesian students reached level 2 or above in mathematics, compared to the OECD average of 69%. At this level, students are expected to interpret simple real-world situations mathematically—a basic indicator of critical thinking. Several factors contribute to these low outcomes, including teacher quality, systemic unpreparedness, and disparities in educational quality across regions. This aligns with findings from various studies indicating that the critical thinking skills of senior high school students in Indonesia, particularly in physics, remain low to moderate. These variations are influenced by teaching quality, learning environments, and the implementation of instructional strategies and methods. According to Yuni Sri Uminingsih (2019), improvements in students' critical thinking skills are influenced by factors such as the quality of instructional delivery. When teachers are able to foster students' motivation to learn physics through the use of standardized teaching tools, students tend to be more actively involved in the learning process.

A preliminary study was conducted at SMAN 1 Majene, a public senior high school in Majene, involving 72 11$^{th}$ grade students in the physics specialization yielded an average critical thinking test score of 72.53 out of a maximum of 100. Individual scores ranged from a low of 40 to a high of 90. Notably, 46.00% of students scored below the minimum proficiency threshold of 75, indicating a relatively low level of critical thinking among these physics-stream students. This outcome suggests that certain instructional components in physics education have not been optimized. To investigate the underlying causes of this shortfall, the researcher conducted a document review of teaching modules used by physics teachers. The review revealed that the predominant instructional model employed was discovery learning, with teaching methods comprising lectures, Q&A sessions, and practical activities using physics kits. Instructional media included animations and educational videos. The researcher opines that the discovery-based instructional strategies applied did not sufficiently promote the development of students' critical thinking skills, as the emphasis remained on conceptual and formula-based application, with inadequate cultivation of analytical abilities.

The development of 21st-century skills—especially critical thinking—necessitates supportive instructional tools, including learning media, teaching modules, Student Worksheets, and specifically crafted critical thinking item indicators (Hanicza et al., 2021). Moreover, the Assessment of Critical Thinking Ability (ACTA) should be developed to accurately assess students' scientific critical thinking, enabling teachers to train these skills effectively (Barus et al., 2020). Developing such instruments is critical as it allows educators to precisely determine students' levels of critical thinking (Abdulah & Wangid, 2021).

Other research indicates that creating physics instructional tools based on Problem-Based Learning (PBL) also enhances critical thinking. Findings show improvements from low to highly proficient levels. These materials were deemed valid, practical, and effective. The integration of PBL contributed significantly to enhancing critical thinking in physics education. This demonstrates that not only PBL but also approaches such as discovery learning, inquiry-based learning, and project-based learning can improve critical thinking skills among senior high school students. Instructional strategies that require students to think actively, solve problems, and reflect on learning have been particularly effective in fostering critical thinking from an early stage (Hidayati et al., 2024).

The implementation of discovery learning through experimental activities has been proven effective in enhancing critical thinking skills among senior high school students. Through exploration and direct observation, students are trained to develop analytical reasoning and problem-solving abilities. Experimental activities encourage active engagement in independently discovering scientific concepts, fostering a reflective and logical mindset essential for learning science. Moreover, this strategy strengthens conceptual understanding, as students learn through authentic experiences, rendering the learning process more meaningful and conducive to the development of higher-order thinking skills (Zahra &

Suwarna, 2023). Discovery-based strategies promote active student participation and create an enjoyable learning atmosphere. Learners are encouraged to independently uncover concepts or principles through observation, experimentation, and conclusion-drawing. This process stimulates students' critical thinking skills, as they are required to analyze information, evaluate evidence, and construct arguments or solutions based on self-developed understanding (Winarti et al., 2021). According to Turrahmah, Susilawati, and Makhrus (2019), discovery learning that employs multi-methods engages students maximally in the learning process, enabling them to find and construct knowledge through diverse methods. Prilliza et al. (2020) emphasize that the multi-methods discovery learning strategy consists of several stages: orientation and problem presentation, formulation of questions and hypotheses, exploration using multiple methods, analysis and conclusion, presentation and reflection, and evaluation and follow-up.

Empirical findings further reveal that the majority of students remain at very low levels of critical thinking, with only a few reaching moderate levels (Septiany et al., 2024). This underscores the necessity for instructional designs that can significantly enhance students' critical thinking skills. Consequently, discovery learning emerges as a viable strategy to facilitate mastery of physics concepts and develop critical thinking competencies. As explained by Onikarini et al. (2019), discovery learning enables students to uncover concepts and theories independently through observation, classification, and exploration. Alongside instructional strategies, the development of relevant learning tools and assessment instruments capable of measuring various dimensions of critical thinking is indispensable. Without well-structured and appropriate strategies, students' critical thinking skills may not develop optimally. Therefore, innovation in both learning strategies and assessment mechanisms is urgently required in the context of senior high school physics education (Chusni et al., 2020).

Research conducted by Ridwan (2021) confirms that discovery learning strategies significantly enhance both critical thinking and academic achievement. This aligns with constructivist learning theory, which posits that learners must engage in problem-solving and self-directed discovery to comprehend and apply knowledge effectively. The discovery learning theory likewise asserts that learning becomes more effective when students are involved in the process of identifying principles or patterns themselves. Furthermore, the implementation of discovery learning with varied teaching methods has been shown to boost both conceptual mastery and critical thinking skills, particularly in physics topics such as measurement, mechanics, and energy (Ramadhani & Ratnawulan, 2022). The strategy fosters student exploration of concepts, while supporting media enhances its overall effectiveness.

Based on the aforementioned problems, this study aims to develop a multi-method discovery learning strategy in physics instruction. The objective is to design and validate learning tools grounded in a multi-method discovery approach, specifically targeting the enhancement of students' critical thinking skills. This strategic development intends to address the current deficiencies in physics instructional strategies. Drawing from previous literature, the researcher has implemented various teaching methods such as expository, experimental, practicum, and simple research-based approaches. To support the effective implementation of these methods, the study utilizes learning tools including teaching modules, lesson plans, student worksheets, and media developed and validated by expert reviewers. The outcomes of this research are expected to contribute significantly to improving the quality of physics education by providing valid, interactive learning tools aligned with constructivist principles and responsive to the demands of 21st-century critical thinking skill development.

## MATERIALS AND METHODS

### Research Approach

This study adopted a descriptive research design, emphasizing the validation of physics instructional materials developed using a multi-method discovery learning strategy. The primary objective was to assess the validity and feasibility of the materials based on evaluations conducted by subject-matter experts in physics education, instructional technology, and multimedia-based learning. The instructional materials were developed by integrating multiple active learning methods within the discovery learning framework to enhance students' cognitive engagement and learning depth. The multi-method approach enabled the incorporation of diverse and complementary pedagogical techniques and resources, aiming to create a more meaningful and interactive learning experience. Data were systematically collected to examine the content, structure, and components of the materials, and to evaluate their alignment with discovery learning principles and the national curriculum. The validation process involved both quantitative and qualitative analyses, utilizing expert review instruments specifically designed to assess the materials' adherence to content standards, pedagogical soundness, and usability.

### Research Instruments and Learning Materials

The instructional materials developed in this study comprised teaching modules, lesson plans, instructional media, and student worksheets, all structured according to the multi-method discovery learning strategy and implemented in the experimental class. Each component was subjected to validation by a panel of expert judges specializing in physics education, instructional media, and curriculum development. The primary research instrument employed was an expert validation sheet, which served as a critical tool in assessing and refining the materials throughout the development process. Both the instructional materials and the validation instruments were systematically designed to support the enhancement of students' critical thinking skills at the senior high school level, aligning with the objectives of the applied instructional strategy.

**Data Analysis Techniques**

The data obtained from the validation of instructional materials—including teaching modules, lesson plans, instructional media, and student worksheets—were analyzed using descriptive qualitative methods. Validation outcomes were classified into four categories: no revision needed, minor revisions required, major revisions required, and not usable/requires further consultation. The validity level of each instructional component was determined based on expert assessments, with materials or instruments deemed sufficiently valid if the average expert score across all evaluated aspects fell within the "valid" range. To further quantify expert agreement and content relevance, the Content Validity Coefficient (Aiken's V) was calculated. The Aiken's V index was employed to assess the degree of expert agreement regarding the relevance of each item using an ordinal scale, where a value closer to 1.00 indicates stronger content validity. In this study, a minimum V-value of 0.75 was used as the acceptance threshold to determine the validity of instructional materials for practical use. This coefficient, derived from experts' ratings for each item, was computed using the formula presented in reference (Aiken, 1985):

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

Description of Aiken's V Formula Variables:

**V** = The Aiken's V coefficient, representing the degree of expert agreement regarding the validity of each item.
***s*** = The score deviation, calculated as the difference between the score assigned by each expert and the lowest possible score in the rating scale (i.e., $s = r - lo$).
**r** = The score assigned to each item by the expert validator.
$\mathbf{l_0}$ = The lowest score in the rating scale used by the validators.
***n*** = The number of expert validators.
***c*** = The highest score in the rating scale used to evaluate item validity.

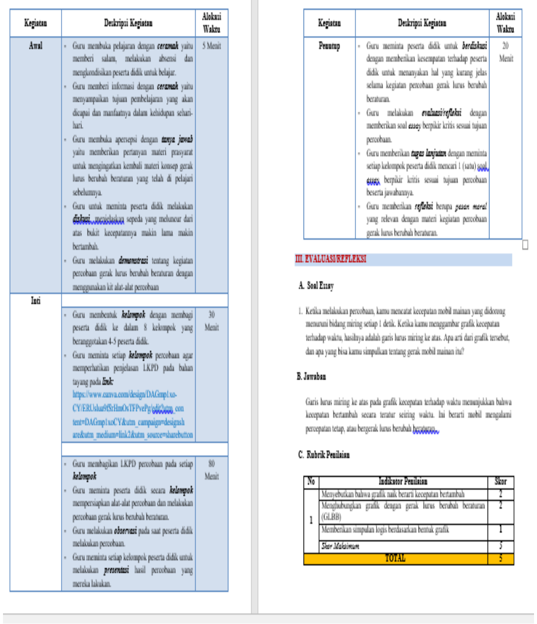
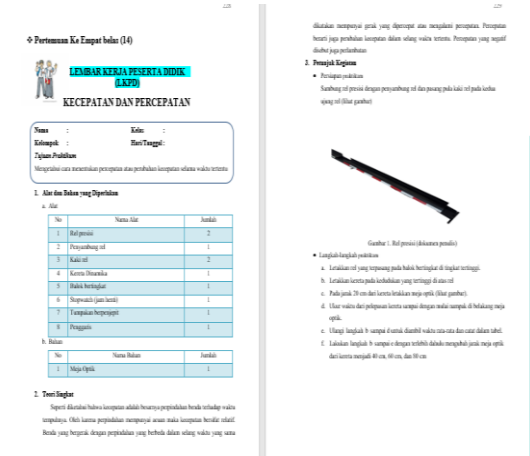
According to Aiken's validation criteria, if the calculated value of the content validity coefficient (V) is greater than or equal to 0.4 ($V \geq 0.4$**)**, the expert agreement index is considered to fall within the valid category**.**

**RESULTS AND DISCUSSION**

The prototype of the developed instructional materials consists of several essential components designed to support the learning process. A detailed description of these components is presented in Table 1 below.

**Table 1** Prototype of Instructional Materials

| No | View | Description |
|---|---|---|
| 1 | <br>Jika Anda ingin mengetahui lebih lanjut tentang konsep gerak sebagai perubahan posisi, *scan QR code* berikut :<br>PENGUATAN KONSEP GERAK<br>3. Contoh Soal Berpikir Kritis<br>1. Menjelaskan pengertian gerak sebagai perubahan posisi<br>*Soal :*<br>Seorang penumpang duduk diam di dalam bus yang sedang melaju di jalan tol. Dari dalam bus, ia merasa tidak bergerak, tetapi orang yang berdiri di pinggir jalan melihat penumpang itu melaju bersama bus. Jelaskan mengapa penumpang di dalam bus bisa dikatakan diam dan sekaligus bergerak, tergantung pada sudut pandang siapa yang mengamatinya!<br>*Jawaban :*<br>Penumpang dianggap diam jika acuannya adalah bus, karena posisinya tidak berubah terhadap bagian dalam bus. Namun, penumpang dianggap bergerak jika acuannya adalah<br>Instructional Materials | Each chapter within the instructional module is comprehensively structured to include clearly defined learning objectives, visually supported content, and concept reinforcement facilitated through QR code scanning linked to interactive technology-based media. Additionally, the module incorporates examples of critical thinking problems, independent practice exercises, a glossary of key terms, and an aligned lesson plan to support systematic learning and skills development. This modular design aligns with constructivist learning principles, promoting active engagement and meaningful knowledge construction through learner-centered resources. |

| | | |
|---|---|---|
| 2 |  Lesson Plan | Each meeting in the lesson plan is systematically organized into subsections, including identity, learning outcomes, facilities and media, and activities based on a multi-method learning strategy supported by animation and video links for the opening, core, and closing sessions. The evaluation and reflection components comprise critical thinking essay questions, answer keys, and detailed assessment rubrics to facilitate comprehensive student assessment. |
| 3 |  Student Activity Sheet (SAS) | Each activity in the Student Activity Sheet is structured into subsections comprising identity, tools and materials, a concise theoretical background, detailed activity guidelines, observation result tables, and a conclusion section. This structure is designed to foster scientific inquiry and develop students' critical thinking skills by guiding them through a systematic and reflective experimental process. |
| 4 |  Learning Media | Each instructional media presentation includes subsections such as learning objectives, concise guiding questions, a QR code for concept reinforcement through interactive technology, and case examples designed for evaluative purposes, hereby promoting student engagement and higher-order thinking development. |

The validation results provided by the experts served as the foundation for revising the instructional materials. Consequently, the revisions were made based on the suggestions and recommendations given by the experts. The instructional devices involved in the learning process comprised: (1) Teaching Materials/Modules, (2) Lesson Plans, (3) Student Worksheets, and (4) Learning Media. Expert evaluations were recorded using a standardized assessment form, with specific comments and recommendations noted in the suggestions column. The names of the validators, as endorsed by the Head of the Educational Sciences Study Program on June 18, 2025, are presented in the following table.

**Table 2** Names of Expert Judgment Validators

| No | Name | Occupation |
|---|---|---|
| 1 | Dr Kahaeruddin, S.Pd., M.Pd. | Lecturer in Physics, Faculty of Mathematics and Natural Sciences (FMIPA), Makassar State University |
| 2 | Dr Arnidah, S.Pd., M.Si. | Lecturer in Educational Technology, Faculty of Education, Makassar State University |
| 3 | Dr Abdul Haris, M.Si. | Lecturer in Physics, Faculty of Mathematics and Natural Sciences (FMIPA), Makassar State University |

**Evaluation Results of the Teaching Materials**

The evaluation results of the teaching materials are as follows:

**Table 3** Evaluation Results of the Teaching Materials

| No | Aspect | Validity Score | Validity Status |
|---|---|---|---|
| 1 | Layout and typography of the module cover | 0,93 | Valid |
| 2 | Module content design (layout, typography of the module content) | 0,82 | Valid |
| 3 | Content material | 0,96 | Valid |
| 4 | Organization/arrangement of material | 0,89 | Valid |
| 5 | Completeness of the module | 0,87 | Valid |
| 6 | Integration of the multi-method strategy aspect | 0,94 | Valid |
| 7 | Conciseness | 0,89 | Valid |
| 8 | Dialogic and interactive | 0,89 | Valid |

Ensuring the content validity of educational modules is crucial to guarantee that the materials are conceptually accurate, relevant, and pedagogically sound. Rigorous validation underpins their effective implementation in instructional settings. Based on the content validity analysis, all evaluated dimensions of the module achieved Aiken's V scores exceeding 0.80, thereby confirming its overall validity as assessed by subject-matter experts. The content aspect received the highest validity score of 0.96, indicating strong alignment with learning objectives, comprehensive coverage, and scientifically accurate information. Expert recommendations prompted targeted improvements to the critical thinking components within the module. These revisions included the addition of clear user instructions, incorporation of summary and reinforcement sections complemented by a glossary, and enhancement of image clarity. Overall, with Aiken's V values ranging from 0.82 to 0.96, the module meets the established standards for content validity and is deemed suitable for instructional use.

**Evaluation Results of the Lesson Plan**

The evaluation results of the lesson plan sheets are as follows:

**Table 4** Evaluation Results of the Lesson Plan

| No | Aspect | Validity Score | Validity Status |
|---|---|---|---|
| 1 | Format | 0,89 | Valid |
| 2 | Language | 0,78 | Valid |
| 3 | Content | 0,81 | Valid |
| 4 | Assessment | 0,86 | Valid |

Based on the data presented, the average validity score for the format aspect was 0.89, indicating it meets the established validity criteria. The language aspect received an average score of 0.78, also satisfying the validity threshold. The content aspect achieved an average validity score of 0.81, while the assessment aspect scored 0.86, both fulfilling the criteria for validity. Collectively, all evaluated aspects were classified as valid. Following expert recommendations, revisions and enhancements were made to the critical thinking skills instrument as outlined in the overall evaluation of the lesson plans. These revisions included the addition of a performance observation instrument, incorporation of Higher Order Thinking Skills (HOTS) questions in the essay tests, and integration of deep learning approach concepts. Overall, the lesson plan was deemed valid across all assessed dimensions and was rated as "good" by the validators, with minor revisions suggested prior to implementation.

**Evaluation Results of the Student Worksheet**

The evaluation results of the student worksheets are as follows:

**Table 5** Evaluation Results of the Student Worksheet

| No | Aspect | Validity Score | Validity Status |
|---|---|---|---|
| 1 | Content | 0,91 | Valid |
| 2 | Language | 0,91 | Valid |

The analysis results presented in the table above show that the average validity score for the content aspect is 0.91, indicating that this aspect satisfactorily meets the validity criteria. Similarly, the language aspect received an average validity score of 0.91, confirming that the Student Worksheet fulfills the required standards of validity. Based on feedback from the validators, several revisions and enhancements were implemented to the critical thinking skill instrument as recommended in the overall evaluation of the Student Worksheet. These revisions included adding detailed instructions for worksheet usage, specifying the learning objectives, clarifying unclear images, and correcting punctuation in the procedural steps. Overall, considering all assessed aspects, the Student Worksheet is deemed valid. Furthermore, the Lesson Plan was rated as "good" by the validators and is considered suitable for use with minor revisions.

**Evaluation Results of the Learning Media**

The evaluation results of the learning media sheets are as follows:

**Table 6** Evaluation Results of the Learning Media

| No | Aspect | Validity Score | Aspect |
|---|---|---|---|
| 1 | Format and Components | 0,85 | Valid |
| 2 | Content | 0,82 | Valid |
| 3 | Language | 0,78 | Valid |

Based on the validity analysis using Aiken's V formula, it was found that all aspects of the instructional media received validity scores above 0.77. This indicates that the developed media fall into the valid category and are suitable for use in learning activities. The aspect with the highest validity score was format and components, with a score of 0.85. This score demonstrates that the instructional media have met the standards of format completeness, both in terms of structure and supporting components. The content aspect received a score of 0.82, also categorized as valid. This score indicates that the material presented in the media aligns with the learning objectives, is relevant to the expected competencies, and is sufficiently clear to assist students in understanding the conveyed concepts. Meanwhile, the aspect with the lowest score was language, with a value of 0.78, which is still within the valid category. Based on some feedback from validators, revisions and improvements were made to the critical thinking skills instrument as suggested in the general assessment of the instructional media. The revisions included adding slides for brainstorming and learning objectives, slides containing case examples and student activities, and slides encouraging students to present conclusions for each topic. Overall, the Aiken's V values ranging from 0.77 to 0.85 confirm that the instructional media meet the content validity criteria. Therefore, the media are considered appropriate for use in learning activities, although minor improvements in language are still necessary to enhance communication effectiveness and interactivity. The assessments from three expert judgments indicated that all subcomponents of the instructional devices were declared valid, while the evaluations from two expert validators regarding the research instruments also showed that all aspects of the instruments met the validity criteria with minor revisions. Consequently, improvements and refinements were made based on the suggestions from the validators. The validity of the instructional devices reflects that the materials, strategies, and learning procedures developed are consistent with the characteristics of physics content and the intended learning objectives

## CONCLUSION

High-quality instructional materials must be validated to ensure their feasibility and usability in actual teaching scenarios, especially when they aim to support complex strategies like multi-method discovery learning in physics. The developed instructional materials were evaluated by expert validators and deemed valid with only minor revisions necessary. Validation focused on content feasibility, construct alignment, and practical usability, all of which exceeded the minimum thresholds for validity. Consequently, the materials are judged suitable for initial, limited-scale trials to assess the effectiveness of the newly designed learning strategy in enhancing students' conceptual understanding and critical thinking skills. In sum, the materials are ready for implementation in controlled learning environments, enabling further evaluation of their educational impact before broader application.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## DECLARATION OF CONFLICT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.


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