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Development of Integrated Case-Based Learning Science Modules on Coconut Shell Waste Management to Improve Science Literacy

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Abstract: Science learning emphasizes not only conceptual understanding but also real- world relevance. A case-based learning approach allows students to explore contextual problems. Therefore, this study develops a science learning module based on case-based learning, integrated with the utilization of coconut shell waste. This study used a Research and Development approach and implementing ADDIE instructional design model. The trial of the learning implementation involved 27 students from class VII E at SMPN 2 Panti. Data collection techniques included expert validation sheets, observation sheets for learning implementation, student response questionnaires, and cognitive tests using a one-group pretest-posttest design. The validity test results showed that the developed module achieved an average score of 92% and was rated as very valid, indicating that it met the standards for truth in content, language, presentation, graphics, and the components of scientific literacy indicators. Furthermore, the practicality test, based on observation sheets from eight meetings, produced an average score of 87% (very practical). Regarding the effectiveness evaluation, because this study used a one-group control design, the findings are interpreted with caution and are not conclusive evidence of an increase in students' scientific literacy. The indicators for explaining scientific phenomena and interpreting scientific data achieved an N-gain of 0.7 (high), while the indicator for designing scientific investigations achieved an N-gain of 0.5 (moderate). The statistical analysis showed a significant difference between the pre-test (27.00) and post-test (73.40) scores. The paired-samples T-Test results, $t(26) = 16.84$, $p < 0.001$, indicate a significant change in scores after the intervention. The average N-gain score was 0.6, which was included in the moderate range. A positive acceptance rate was also evident in the student response questionnaire, with a 81% score. Based on all results, it was concluded that this integrated local potential learning module improves students' scientific literacy.

Keywords: case-based learning, coconut shell waste, local potential, science module, scientific literacy.

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INTRODUCTION

Literacy skills have become crucial in facing the challenges of the 21st century. One particularly important type of literacy is scientific literacy. Scientific literacy plays a crucial role in researching various aspects of life, including environmental issues, technological developments, economic conditions, public health, and social problems (Anggita et al., 2024; Trullàs et al., 2022; Wijaya et al., 2024). Scientific literacy is also considered a competency for identifying scientific issues and expressing viewpoints based on scientific and technological knowledge (Billah et al., 2025; Purwasih et al., 2025). Furthermore, in daily life, scientific literacy is needed to make informed decisions, engage with social and cultural issues, and improve economic productivity (Rudolph, 2023).

Low levels of scientific literacy are among the main challenges facing Indonesia's education system. A total of 52% of the countries participating in PISA (Program for International Student Assessment) 2022 experienced a decline in science literacy scores compared to PISA 2018 (Ministry of Education and Culture, 2022). Data from an international PISA study on science literacy in Indonesia, conducted by the OECD (Organization for Economic Co-operation and Development) in 2018, showed a score of 396, placing Indonesia at 70th out of 78 participating countries (Hakim et al., 2025; Yusmar & Fadilah, 2023). Additionally, at the national level, various assessments indicate that most secondary school students still demonstrate low scientific literacy. This condition is also evident in several regions, particularly in Jember Regency, as evidenced by research by Fuadina et al. (2022), which reported that one school, SMPN 3 Jember, had an average science literacy score of 69.87. This data indicates a systemic urgency to immediately revitalize the science learning approach in the Jember region, particularly, and in Indonesia in general (Gillies, 2023).

The root causes of low levels of scientific literacy are diverse, one of which stems from the suboptimal implementation of the education and learning system in the classroom (Ye & Yuan, 2022). Various factors are suspected to be the main cause, ranging from the selection of irrelevant learning models and approaches to limited facilities and learning resources (Fortus et al., 2022). A review of currently available science teaching materials and textbooks shows that most are text-based (heavily reliant on narrative text) and tend to be theoretical (Papakonstantinou & Skoumios, 2021). The content in these teaching materials often fails to align with students' daily realities, thereby failing to build a cognitive bridge between scientific concepts and phenomena in their immediate surroundings (Batubara et al., 2022; Huang et al., 2022; Torkar et al., 2022). Consequently, the integration of science literacy into the learning process appears rigid and fails to boost student motivation. This leads to boredom and difficulty in developing a meaningful understanding of the material. Factors influencing the improvement of science literacy include the selection of instructional models, approaches, learning strategies, and learning resources used during instruction (Mulyono et al., 2024; Syofyan et al., 2025). This statement aligns with the findings of Putra et al. (2023), which indicates that learning resources, such as textbooks and teaching materials, are insufficiently integrated into daily life (Akour & Alenezi, 2022; Almasri, 2024; Marougkas et al., 2023).

As a strategic effort to address these issues, intervention is needed through learning resources that are adaptive, supportive, and relevant to students' characteristics and ecological needs (María et al., 2024). A review of the existing literature confirms that optimal achievement of science literacy indicators is positively correlated with the availability of appropriate teaching materials, such as e-modules or print modules (Eliza et al., 2025; Wicaksono et al., 2026). Modules offer pedagogical advantages because they are systematically organized to follow the curriculum flow and are designed into measurable learning units (Pujawan et al., 2022). These characteristics provide students with the flexibility to manage the learning process independently or collaboratively, to elaborate, and to help them master the targeted competencies without always relying on direct teacher instruction (Karlen & Hertel, 2024; Le et al., 2022)

While leveraging local resources is a recognized strategy for advancing scientific literacy, current educational materials often remain stuck in a descriptive phase, focusing heavily on documenting cultural customs or economic values (Astawan et al., 2025; Dwita et al., 2023; Osborne & Allchin, 2025). For instance, recent research on coconut shell waste in Jember has primarily emphasized economic empowerment through handicraft manufacturing (Kumar & Saha, 2024; Rizal & Suryani, 2022). This study introduces a pivotal pedagogical transition by adopting Case-Based Learning (CBL) as its foundational framework. Unlike traditional local potential modules that are largely informative (Wahyuni et al., 2025). This CBL-integrated module is inherently investigative. It moves beyond treating coconut waste as merely a commodity, instead requiring students to analyze environmental consequences, evaluate the waste's physical and chemical properties, and synthesize scientific solutions through active problem-solving (Makhlouf & Rabahi, 2025).

Previous efforts to develop module-based materials for science literacy, such as those by Astawan et al. (2025), focused on ethoscience and local resources. However, these developments have primarily focused on ethnoscience and the integration of local resources. These modules tend to emphasize descriptive content on cultural practices or local potential, with limited engagement in higher-order thinking. As a result, students are often positioned as passive recipients of information rather than active problem solvers. In addition, these modules generally lack integration of structured instructional approaches, such as Case-Based Learning, that can facilitate inquiry, analysis, and decision-making. The absence of authentic, real-world problem scenarios also limits students' opportunities to apply scientific concepts in meaningful contexts. Furthermore, the integration of scientific literacy indicators is often not explicitly designed, which may reduce the effectiveness of these modules in systematically developing students' scientific literacy skills (Ainur et al., 2025).

In the Jember Regency, the agricultural sector produces significant by products, such as coconut shells, which are often discarded or burned, leading to hygiene issues and air pollution. Scientifically, this waste has high utility when processed using applied technologies into products such as briquettes or liquid smoke fertilizer. Integrating these localized environmental challenges into science education creates a more authentic learning experience, which has been shown to significantly bolster students' scientific literacy. From an educational perspective, integrating locally relevant environmental issues into science learning provides an opportunity to bridge the gap between abstract scientific concepts and students' real-life experiences (Wardhani et al., 2024).

A critical review of the literature reveals a significant research gap, while learning modules, local potential, and CBL have been studied independently, no comprehensive research has integrated all three into a single instructional resource for junior high school science. Specifically, the use of coconut shell waste management in Jember as a primary medium for developing science literacy remains unexplored. Prior studies, such as Guerrero & Sjöström (2025), focused on community economic training rather than curriculum-aligned instructional design to address low literacy levels in schools. By utilizing case-based learning, an approach that centers on case studies as the primary medium (Stanley, 2021).

This module encourages student collaboration and critical thinking. To guide the investigation, this study poses the following questions: How valid and practical is the developed CBL-based science module integrated with local potential for junior high school students? How effective is the developed module in improving students' scientific literacy skills? In line with these questions, it is hypothesized that the developed module is valid and practical for science learning and that its implementation significantly improves students' scientific literacy skills.

METHOD

Participants

This study was conducted on 27 7th-grade students from class E at SMPN 2 Panti. This study was conducted in the odd semester of the 2025/2026 academic year. The study used purposive sampling, selecting participants who had never studied matter and its changes.

Research Design and Procedures

This development research employed the ADDIE model, which consists of five stages. An analysis stage was conducted to identify students' initial levels of scientific literacy and the challenges faced in science learning at SMPN 2 Panti. Classroom observations were carried out to examine students' participation, interaction patterns, and engagement in learning activities, particularly in relation to scientific literacy indicators. (Wahyuni et al., 2024). In addition, semi-structured interviews were conducted with a science teacher to gather detailed information regarding the instructional strategies, teaching materials, and modules currently used. The analysis also included identifying gaps between expected competencies and actual classroom practices. The findings from this stage served as the foundation for designing an instructional module that addresses these identified needs.

Based on the results of the analysis stage, the researcher designed a case-based learning module focusing on coconut shell waste processing within the topic of substances and their changes. The design process was guided by several pedagogical principles. First, contextualization, where learning activities were developed based on real-world problems related to local environmental issues. Second, science literacy orientation, in which all activities were aligned with three core competencies: explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting scientific data and evidence (Ashari et al., 2023). Third, student-centered learning where students were positioned as active learners through collaborative tasks and problem-solving activities. Fourth, inquiry-based learning, where students were encouraged to explore case scenarios, formulate hypotheses, conduct simple investigations, and draw conclusions. Fifth, scaffolding, where learning tasks were systematically structured from basic understanding to higher-order thinking processes.

At the development stage, the researcher conducted a product validity test using expert validators, who completed the provided validation sheets. If the module received suggestions from the validators, revisions were made in accordance with their feedback and recommendations. The validation process assessed several aspects, such as content accuracy, relevance to the curriculum, alignment with scientific literacy indicators, clarity of language, visual design, and the suitability of learning activities (Istyadji & Sauqina, 2023). Based on the initial feedback, the module was revised to shar instructional directions, strengthen contextual relevance, and ensure the clarity of all scientific explanations (Coppi et al., 2023).

Once the validators deemed the module valid, the implementation phase began, including classroom testing with students and a teacher, while independent observers documented the process. This stage centered on a collaborative learning environment in which students worked in groups to analyze case scenarios, conduct simple experiments, and present their collective findings (Zhang et al., 2025). The effectiveness of the intervention was examined using a weak experimental design, namely a one-group pretest-posttest design, due to the absence of a comparison or control group. In this approach, a single group of students completed a pretest before and a posttest after using the local potential-based e-module to assess potential improvements in their science literacy (Maurer et al., 2026). The subsequent evaluation stage focused on assessing the practicality and effectiveness of the developed module through pretests and posttests (Funa, 2026). During this phase, the researchers integrated feedback from validators, observers, and students to further refine the material. To precisely measure the progress in students' scientific literacy, the results were analyzed using N-gain scores. Ultimately, these evaluation outcomes determined the module's overall feasibility and success as an instructional tool for enhancing scientific literacy.

Instrument

This study utilized a combination of test and non-test instruments to gather comprehensive data on student scientific literacy and the overall utility of the developed module. The instruments are described comprehensively below.

Test Instrument

To establish a baseline of initial abilities and measure subsequent growth, pretest and posttest were administered before and after the intervention, respectively. This instrument was adapted from the PISA 2025 scientific literacy framework and then contextualized to Jember's local potential for coconut shell waste. There are three main scientific literacy indicators measured, namely: (1) explaining phenomena scientifically, (2) evaluating and designing scientific investigations, and (3) interpreting data and evidence scientifically (OECD, 2023). Prior to implementation, empirical tests of construct validity and reliability were conducted. The pretest and posttest instruments consist of 12 questions: 9 multiple-choice and 3 essay. The essay questions are included to assess higher-order thinking skills, particularly reasoning and explanation. Table 1 shows the description of the pretest-posttest instrument.

Non-test Instrument

In addition to testing, non-test instruments played a vital role in ensuring the quality of the

Table 1. Description of test instruments

No	Science Literacy Indicator	Meaning of the instrument	Example of a test item
1	Explaining scientific phenomena	Demonstrates student comprehension of changes in states of matter that occur during the processing of coconut shell, such as combustion and heat transfer.	The vapor produced during the combustion of coconut shells is considered a change in state of matter because...
		Assesses the skill of differentiating the physical and chemical changes in the process of mixing the materials used in producing coconut shell briquettes.	Mixing coconut shell charcoal powder with tapioca flour and water results in…
2	Evaluating and designing scientific investigation	Assess students' skills in interpreting density data for materials used to make briquettes from coconut shells.	Given mass and volume data of objects, which object has the greatest density?
		Evaluates knowledge of floating and sinking when testing the quality of briquettes depending on density.	Why does one briquette sink while another floats in water?

3	Identifying scientific investigation	Measures the ability to detect physical and chemical changes that take place when burning coconut shells into charcoal.	The vapor produced during burning processes is an example of…
4	Identifying scientific evidence	Evaluates the skill of students to identify correct actions to identify physical and chemical changes in the processing of materials.	What is the first step to identify whether a change is physical or chemical?
5	Interpreting scientific data and evidence	Assesses knowledge of chemical reactions using comparisons with the processes that relate to combustion when making coconut shell charcoal.	Overcooked food becomes darker and bitter. This indicates…
		Evaluates the capacity to create basic research into temperature impacts, relevant to the heating activities during the coconut shell process.	How would you investigate the effect of temperature on ice cream melting time?
6	Explaining scientific phenomena (Essay)	Measures define the behavior of particles in various states of matter, as in the heating and combustion of coconut shells.	Explain the differences between particle arrangement in solids, liquids, and gases...
7	Evaluating scientific investigation (Essay)	Assesses logical skills to differentiate physical and chemical modification in actual processes, relevant to the burning of coconut shell and the changing of the material.	Explain the difference in the change in state of matter between melting candle wax and burning paper...
12	Interpreting data and evidence (Essay)	Measures the ability to calculate density and predict the floating/sinking behavior of materials, which is important in assessing the quality of briquettes.	Calculate density and determine whether an object will float or sink in water...

instructional material. Expert validation sheets were used to assess the module's validity with respect to content, design, and linguistic clarity. Furthermore, observation sheets enabled evaluation of the module's practicality during classroom implementation, while student response questionnaires provided insights into learners' perceptions of the process. Non-test instruments consist of: (1) a validator's response sheet, (2) an observation sheet for learning implementation, and (3) a questionnaire for students' responses. The expert validation sheet was adapted from Kosasih (2021) and rated the aspects of content, context, scientific literacy, language, and graphics. Each item was rated on a 5-point Likert scale by three validators. Content validity for each item in the validation instrument was quantified using Aiken's V coefficient, a recommended statistic for expert judgment. The description of the expert validation sheet is shown in Table 2.

The learning implementation observation sheet was used by three independent observers at eight learning sessions to evaluate the applicability of each step of the module activity. One of the items was, "Students can identify and formulate problems in the cases in the worksheet,"

Table 2. Description of content validity by experts

No	Assessment Aspect	Meaning of the Instrument	Example of Item
1	Content Feasibility	Evaluate the suitability and completeness of the module content, and its alignment with the learning objectives.	The suitability of systematically structured module components (including learning objectives, instructions, worksheets, keywords, and evaluations).
		Measuring the use of modules for independent and classroom learning in the context of science learning.	The module can be used independently by students.
2	Contextual Relevance	Assess how well the material connects scientific concepts with real-world applications, particularly coconut shell waste processing.	Suitability of module activities with the material studied.
		Evaluate the integration of case study-based learning and local potential into module content.	The module incorporates case-based learning in the presentation of material.
3	Scientific Literacy	Measuring the alignment of content and activities with scientific literacy indicators (understanding, reasoning, and application)	Module activity assignments reflect indicators of scientific literacy.
		Assess whether the module supports students' development of scientific literacy through contextual activities.	Student materials and activities help students improve their scientific literacy.
4	Language	Evaluate clarity, readability, and appropriateness of language for students' ability level.	The language used is easy for students to understand.
		Measure whether the language encourages student engagement and interest in learning.	The language used encourages students' interest in learning.
5	Graphics	Assess the quality of visual design, including layout, typography, and color combinations.	The module presentation design attracts students' interest in learning.

scored from 1 (not observed) to 4 (fully observed). The Description of the observation instruments is shown in Table 3.

The questionnaire for students contained 20 items on a 4-point Likert scale, rating the aspects of material content, language, and graphics

Table 3. Description of the observation instruments

No	Learning Session	Meaning of the Instrument	Example of Observation Item
1	Learning Activity 1	Assessing the stages of the case-based learning model applied by teachers and	The teacher provides a case-based learning module on coconut shell waste processing, covering the

		followed by students in the material Substances and Their Changes.	effects of substances on students.
2	Learning Activity 2	Measures teachers' ability to explain scientific concepts (states of matter, change, density) in real-world contexts.	The teacher explains the concept of matter and its changes using examples from daily life.
3	Learning Activity 3	Assessing the integration of real cases into learning activities.	The teacher presents a case study of waste processing in the surrounding environment and shows a picture that illustrates the phenomenon.
4	Learning Activity 4	Assess student participation in problem-solving activities.	The teacher directs students to work on the worksheet for learning activity II in the provided module.
5	Learning Activity 5	Measures students' ability to analyze, interpret, and draw conclusions from scientific evidence in context.	The teacher assigns several students to analyze the phenomenon, and they explain the material again in relation to it.
6	Learning Activity 6	Evaluate student worksheets and assignments in the module in groups.	Students analyze a case in the module with their group members by reviewing the module's information.
7	Learning Activity 7	Assesses students' ability to present and communicate their findings	The teacher asks several students to present their answers in class.
8	Learning Activity 8	Measures how teachers evaluate student understanding through discussions, assignments, and tests.	The teacher provides a video and asks students to answer based on an analysis of problems relating to physical and chemical changes.

(Alwadei & Mohsen, 2023). The description of the students' response instruments is shown in Table 4. Collectively, these instruments ensured a robust analysis of the module's validity, practicality, and effectiveness.

Data Analysis

The validity test is based on the research by Kusmaryono et al. (2022), which used Equation 1, and the validity criteria are summarized in Table 5. The development of e-

Table 4. Description of students' response instruments

No	Indicator	Meaning of the Instrument	Example of Item
1	Interest (Attractiveness)	Measures students' level of interest, motivation, and engagement when using the module	The module's appearance is attractive.
2	Interest (Attractiveness)	Assess students' learning interests independently using the module.	This module motivates me to study independently.
3	Content (Material Quality)	Evaluate the clarity, organization, and systematic presentation of scientific content related to real-life contexts.	The material is presented in a structured and easy-to-understand format.

4	Content (Material Quality)	Measuring the relevance of learning materials to students' daily lives.	The problems presented in this module relate to real-life situations.
5	Content (Material Quality)	Assess the completeness and usefulness of information in supporting student understanding.	The information provided in this module is complete and relevant.
6	Content (Material Quality)	Evaluate the effectiveness of assignments and activities in helping students master the material.	The tasks in the module help me to understand the material.
7	Language	Measures the clarity and readability of the language used in the module	The language used in the module is clear and easy to understand.
8	Language	Assess students' comfort and ease in learning due to the use of language.	The sentences in this module make learning comfortable.
9	Language	Evaluate the proper use of terms, including explanations of unfamiliar or foreign terms.	Foreign or scientific terms are clearly explained in this module.

modules is considered valid if the minimum score is 70.01%–85% and the category is valid.

$$V = \frac{\sum x}{\sum x_{max}}$$

(Equation 1)

where, v is the percentage of validity; Σx is the total score; and Σx_{max} is the maximum total score. The practicality test refers to the research by Kusmaryono et al. (2022), which uses Equation 2, and the criteria for practicality are shown in Table 6. The development of e-modules is considered practical if the minimum score in the practical category is 70.01%–85%.

$$P = \frac{T_{Se}}{T_{Sh}}$$

(Equation 2)

where, P is the percentage of practicality; T_{se} is the total score; and T_{sh} is the maximum total score.

Table 5. Validity criteria

Percentage of validity (%)	Criteria
$85 < V \leq 100$	Very Valid
$70 < V \leq 85$	Valid
$40 < V \leq 70$	Less Valid
$25 < V \leq 40$	Invalid

Table 6. Practicality criteria

Percentage of practicality (%)	Criteria
$85 < P \leq 100$	Very Practical
$70 < P \leq 85$	Practical
$40 < P \leq 70$	Less Practical
$25 < P \leq 40$	Impractical

The effectiveness of the e-module was analyzed using pre-test and post-test results. Following Hake (1998), the effectiveness criteria are shown in Table 7. The development of the e-module is considered adequate if the average N-gain score is at least $0.3 \leq \langle g \rangle < 0.7$ which is classified as Moderate.

Table 7. Effectiveness criteria

N-gain Score	Criteria
$\langle g \rangle \geq 0.7$	High
$0.3 \leq \langle g \rangle < 0.7$	Moderate
$\langle g \rangle < 0.3$	Low

The criteria for student responses are presented in Table 8. The development of e-modules is considered Good if the minimum student response score is between 60.01% and 80%.

Table 8. Student response criteria

Student Response Score (%)	Criteria
$80 < R \leq 100$	Very Good
$60 < R \leq 80$	Good
$40 < R \leq 60$	Fairly Good
$25 < R \leq 40$	Poor

RESULT AND DISCUSSION

This study aims to address two main research questions concerning the development and implementation of a Case-Based Learning science module integrated with local potential for junior high school students. The first question examines the validity and practicality of the developed module for science learning. The second question investigates how effective the module is at improving students' scientific literacy. To answer this, there are several stages, each providing systematic evidence to support the validity, practicality, and effectiveness of the developed module.

Identification of Environmental Problems and Learning Needs

The analysis stage of this study began with identifying students' needs at SMPN 2 Panti through direct observation of the science learning process. Observations were conducted to determine students' ability to understand science concepts in everyday life. Observations indicated that some students still struggled to connect science concepts to real-life phenomena (Kim & Park, 2024; Zulfa et al., 2025). This was reinforced by interviews with science teachers, who stated that the underlying problem was that learning resources were largely limited to library books, government textbooks, and general modules that were not fully contextualized with students' real-life environments. This made it difficult for students to connect science concepts to everyday life. Although the modules used were generally relevant, they did not integrate the local environmental context, which could serve as relevant examples in science learning. One local resource that could be integrated into students' surroundings is coconut shell waste, which is currently underutilized, providing a basis for designing a module that integrates local resources to support contextual science learning through case studies.

Figure 1. Local potential in the form of coconut shell waste

Designing Integrated CBL Science Module

The design stage commenced with the creation of an initial module draft, informed by the preceding needs analysis. These instructional resources, focused on the theme of substances and their transformations, center on the scientific processing of coconut shell waste. This module was developed in accordance with the components proposed by Kosasih, including learning objectives, module guidelines, learning materials, worksheets, worksheet answer keys, evaluation sheets, and evaluation answer keys (Kosasih, 2021). This module was designed using the Canva Pro application with integrated visual elements, images, animations, and color schemes and font sizes to enhance its visual appeal, while ensuring alignment with the Merdeka Curriculum implemented at SMPN 2 Panti. The module cover includes the title, an image of a coconut shell, the target school level, and the author's identity, while the introduction section contains learning outcomes, learning objectives, usage instructions, and case-based learning syntax.

Figure 2. Module cover

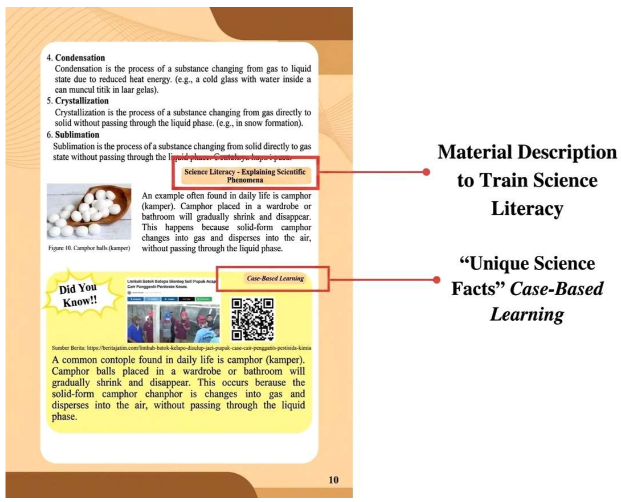

Figure 3. The module incorporates three scientific literacy indicators and a case-based learning approach

The module was developed using local potential found in the students' surroundings, particularly coconut shell waste in the Panti District. This local context is reflected in both the cover design and the module content, which integrates coconut shell waste processing as a learning context. The module content is systematically organized from the introduction to the evaluation stage to facilitate students' learning. The learning materials are divided into four learning activities, namely states of matter and particle models, changes in the state of matter, physical and chemical changes, and density of substances, all of which were determined based on the school curriculum analysis.

Each learning activity and material description in the module incorporates three scientific literacy indicators and a case analysis relevant to students' real-life environments. In addition, the module includes "unique science facts" based on the case-based learning approach, enriching students' understanding of the topics and strengthening their case analysis skills. The student worksheets are also designed using case-based learning and integrate local potential for coconut shell waste processing. One example includes activities that require students to watch a video on making briquettes from coconut shell waste and complete a table listing the three scientific literacy indicators, helping

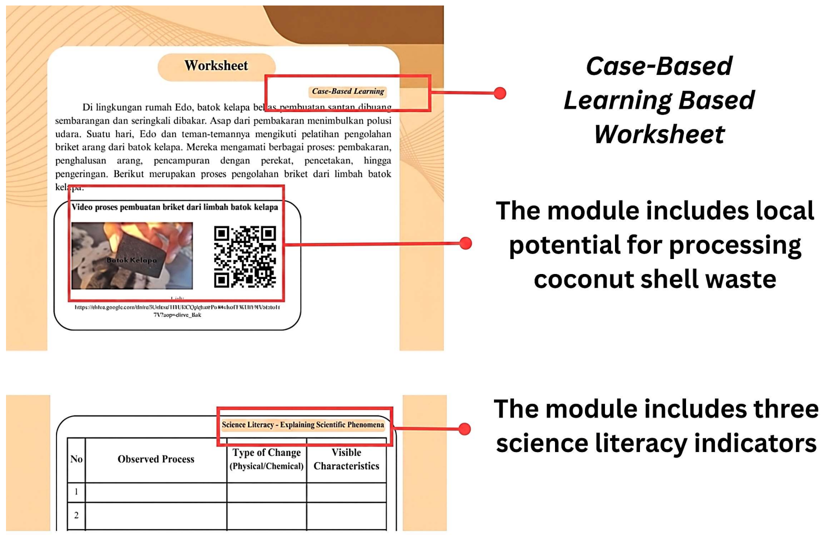

Figure 4. Student activities in the module incorporate three scientific literacy indicators and a case-based learning approach

students identify observed processes, types of change, and scientifically observable characteristics.

Module Development and Expert Validation

In the next stage of development, validation tests were conducted on test items and the modules designed by the researchers. The results of the validation test items' corrected item-total correlation analysis showed that 6 questions (numbers 1, 2, 3, 7, 11, and 12) were declared valid, with calculated r values> 0.381. Meanwhile, the other 6 items did not meet the validity criteria. Items that lack empirical validity are revised based on expert input to inform further instrument development. In this study, the Cronbach's Alpha coefficient was 0.645, which is lower than what is generally recommended (0.70) for high-stakes tests (Menon et al., 2025). This suggests that the instrument's internal consistency is acceptable, but perhaps not yet ideal. This may be due to multiple factors, such as the small number of items, the use of multiple item formats (multiple-choice and essay), and the small sample size (Ikhsanudin et al., 2024; Xiao et al., 2024). Finally, the fact that science literacy is a multidimensional construct may also contribute to lower internal consistency (Intasoi et al., 2020). Although the instrument is deemed reliable enough for exploratory purposes, this should be noted, and future research should aim to improve its reliability. Recapitulation of cognitive test instruments results presented in Table 9.

Table 9. Results of empirical analysis of cognitive test instruments

Test component	Results analysis	Criteria	Interpretation
Empirical construct validity	6 items (1, 2, 3, 7, 11, 12)	r > 0.381	Valid
	6 items (4, 5, 6, 8, 9, 10)	r < 0.381	Need Revision
Reliability (Cronbach's Alpha)	0.645	α> 0.60	Reliable (sufficient)

Module validation was carried out by three validators: two lecturers from the Science Education undergraduate program at the University of Jember and one science teacher at SMPN 2 Panti. The lecturers were selected for their expertise in science education and instructional design. At the same time, the teacher was chosen for their direct classroom experience and familiarity with students' characteristics and curriculum implementation. Each validator evaluated the module based on several aspects, including content accuracy, language clarity, presentation, graphical design, and alignment with scientific literacy indicators, and provided both quantitative scores and qualitative feedback for improvement. The validation results were then analyzed using a calculation formula and categorized according to the validation criteria. The validation process used a validation assessment sheet covering content, language, presentation, graphics, and scientific literacy. Each expert provided scores, comments, and suggestions for improvement on the parts that needed refinement. The results of the module validation are shown in Table 10 below.

The results of the module validation analysis show that all assessment aspects achieved the "Very Valid" category, with an average percentage score of 92%, as shown in the table, indicating that the module is suitable for use in learning. The content aspect, which includes module components such as learning objectives, usage instructions, material descriptions, worksheets, keywords, and evaluations, received an overall score of 92%. The contextual aspect achieved a high score of 93%, reflecting the integration of local potential through coconut shell waste processing and the application of a case-based learning approach. The scientific literacy aspect scored 92%, the language aspect 91%, and the graphic aspect 92%. The validators gave specific feedback for improvement during the validation process. Validator 1, a science education lecturer, indicated that some of the questions in the worksheets of Learning Activity 2 (Changes in the State of Matter) were not well aligned with the "evaluating and designing scientific investigations" indicator, as the questions did not explicitly prompt students to propose a hypothesis or identify variables.

Table 10. Results of the validation analysis of the case-based learning module on coconut shell waste processing

No	Assessment Aspect	Validator Percentage (%)			Percentage (%)	Criteria
		1	2	3		
1.	Content Aspect	88	88	100	92	Very Valid
2.	Contextual Aspect (Material)	88	93	100	93	Very Valid
3.	**Scientific Literacy Aspect**	90	85	100	92	Very Valid
4.	Language Aspect	84	96	92	91	Very Valid
5.	Graphic Aspect	84	92	100	92	Very Valid
Average Validation Score		87	91	98	92	Very Valid

As a result, the research team modified three items on the worksheet to explicitly require students to specify the independent, dependent, and control variables before designing their experimental procedure. Validator 2 noted that some of the case studies had vocabulary that would be too difficult for seventh-grade students. The text was revised, and a glossary of science vocabulary was added to each learning activity in response to this. The classroom teacher (validator 3) recommended that the learning objectives at the start of each activity be phrased in plain student language rather than curriculum-specific terms; this was done to enhance readability. The fact that the language aspect (91%) received a lower score than the contextual aspect (93%) of the activity indicates these initial concerns about readability, which were revised in the activity as described above. After validation, the module was revised based on the validators' suggestions before being implemented in the learning process. Subsequently, if the module was deemed feasible in the validation results, the revised module was ready for implementation.

Aiken's V values ranged from 0.833 to 1.000 across the 27 items, with average aspect levels of V = 0.950 (Content), V = 0.948 (Contextual), V = 0.896 (Scientific Literacy), V = 0.883 (Language), and V = 0.917 (Graphics), resulting in an overall average V = 0.923. All values exceeded the recommended minimum threshold of V = 0.75 for a three-judge panel (Aiken, 1985), indicating that all items were rated as highly relevant and representative of the construct being measured. Regarding inter-rater agreement, 96.3% of items (26 of 27) received scores within the 1-point range across the three validators, indicating a high level of practical agreement. The results of the content validity analysis using Aiken's V are presented in Table 11.

Table 11. Aiken's V content validity results

No	Assessment Aspect	Aiken's V
1.	Content Aspect	0.950
2.	Contextual Aspect (Material)	0.948
3.	**Scientific Literacy Aspect**	**0.896**
4.	Language Aspect	0.883
5.	Graphic Aspect	0.917
	Average of Aiken's V Score	0.923

Practicality Testing of the Developed Module

The next stage was the implementation of the validated module, which was deemed suitable for testing with students in class VII E at SMPN 2 Panti, involving 27 students. This stage aims to test the module's practicality by measuring its effectiveness using an observation questionnaire on learning implementation. Assessment data were obtained from three observers who observed the learning process during the module implementation. The module was implemented over eight learning sessions. Throughout the implementation process, the observers conducted direct observations of each stage of learning, including student and teacher activities, in accordance with the guidelines in the observation instrument. Results of the implementation observation are presented in Table 12.

Table 12. Results of the analysis of the implementation observation of the case-based learning module on coconut shell waste processing

No.	Activity Aspect	Total Score (%)			Criteria
		O1	O2	O3	
1.	**Summarizing the material description in the module**	87	89	89	Very Practical
2.	Identifying problems in the worksheet	87	87	93	Very Practical
3.	Using information from the module to address material-related problems	83	93	90	Very Practical
4.	Providing solutions to problems through group discussions by completing the worksheet	93	80	80	Pratical

5.	Writing conclusions from group discussions to answer the worksheet in the module	93	87	93	Very Practical
6.	Presenting discussion results	86	91	91	Very Practical
7.	Providing an evaluation of students' answers	80	90	70	Practical
	Average (%)				Very Practical

The implementation stage of the module uses data from the learning implementation observation questionnaire, completed by three observers, to determine whether the developed module is practical and easy to use in achieving the success indicator of increased scientific literacy. Based on the results of the learning implementation observation, the developed module shows a high level of practicality, with an average score of 87%, placing it in the "very practical" category. These results indicate that, in general, this module can be easily used by students and teachers without hindering the learning process. The scores of the individual activities provide insights into different levels of practicality. The highest practicality score (91.00%) was observed in activity 5, in which students were asked to write conclusions from their group discussions to complete the worksheet. This is due to the clear guidelines for writing conclusions embedded in the module, which allowed students to follow a template independently, leading to less confusion and a more seamless learning experience (Houghton, 2023). On the other hand, the lowest average score (80.00%, Practical) was recorded for activity 7, "Providing evaluation of students' answers". Even so, the total implementation scores fell into the very practical category (>80%), indicating that the module was highly practical for classroom use. The results, however, indicate that more detailed assessment rubrics and more organized observation guidelines should be used in future research to enhance inter-rater consistency across studies, as reliability research has highlighted the importance of standardized evaluation processes (Jönsson et al., 2025).

Evaluation of Module Effectiveness in Improving Science Literacy

A paired-sample t-test was conducted to evaluate the impact of the Case-Based Learning module on students' scientific literacy scores. There was a statistically significant increase in scores from the pre-test (M = 27.00, SD = 11.88) to the post-test (M = 73.40, SD = 10.63), $t(26) = 16.84$, $p < .001$. The mean increase in scientific literacy scores was 46.40 with a 95% confidence interval. These results indicate that implementing the integrated CBL module significantly improved students' scientific literacy. The results of the paired-samples t-test are shown in Table 13.

Table 13. Result of the paired sample t-test

Variable	N	Mean	SD	t-value	df	p-value (Sig. 2-tailed)
Pre-test	27	27.00	11.88	-	-	-
Post-test	27	73.40	10.63	-	-	-
Differences (Post-Pre)	27	46.40	14.30	16.84	26	<0.001

Based on the increase in scientific literacy, as indicated by pre-test and post-test scores for each indicator, all three indicators increased after the implementation of the case-based learning module.

Based on Table 14, the average student score increased from 27 to 73, with an N-gain of 0.6, which is classified as moderate. This indicates that the module improved students' scientific literacy. An N-gain score in the moderate

Table 14. Results of pretest and posttest analysis with N-gain scores

No	Science Literacy Indicators	Average Pre-test (%)	Average Post-test (%)	N-gain	Criteria
1.	Explaining phenomena scientifically	28.00	78.40	0.70	High
2.	Evaluating and designing scientific inquiry	25.00	62.50	0.50	Moderate
3.	Interpreting data and evidence scientifically	26.00	77.80	0.70	High
Total Average		27.00	73.40	0.60	Moderate

category indicates that the learning intervention, namely the case-based learning module, was effective in significantly strengthening students' conceptual understanding, even though the improvement did not reach the high category for all students. This finding is consistent with recent research showing that context-based, problem-based, and case-based learning modules generally lead to moderate to great improvements in learning outcomes, as they provide a more meaningful and well-structured learning experience (Putra et al., 2023; Safitri et al., 2026).

Despite the overall improvement in students' scientific literacy, an interesting variation can be observed among the three indicators. The indicator evaluating and designing scientific inquiry achieved a lower N-gain score compared to explaining scientific phenomena and interpreting data and evidence, both of which reached a high category. This disparity suggests that students encountered greater challenges in developing higher-order scientific inquiry skills. One possible explanation lies in the cognitive demands of the indicator itself. Evaluating and designing scientific investigations requires more complex thinking processes, such as formulating hypotheses, identifying variables, designing procedures, and critically evaluating evidence. These skills are inherently more demanding than explaining concepts or interpreting data, particularly for junior high school students who may still be developing their higher-order thinking abilities (Kwangmuang et al., 2021).

In addition, this finding may be related to the module's learning activities. Although the module incorporates case-based learning, the activities may place greater emphasis on understanding phenomena and analyzing data rather than explicitly guiding students through the process of designing investigations. As a result, students may have had fewer opportunities to practice inquiry design in a structured and scaffolded manner. Another possible factor is the difficulty level of the assessment instrument used to measure this indicator. If the test items require abstract reasoning or unfamiliar experimental design contexts, students may struggle to demonstrate their actual understanding, leading to lower N-gain scores. This suggests that the alignment between learning activities and assessment tasks should be carefully considered to ensure that both support the development and measurement of inquiry skills.

Therefore, while the module has been effective in improving overall scientific literacy, these findings highlight the need for further refinement, particularly in strengthening activities that support inquiry-based skills. Future improvements could include more explicit scaffolding, guided investigation tasks, and iterative practice in designing simple experiments, so that students can gradually develop stronger competencies in scientific inquiry.

This improvement can be attributed to the module's specific design features, grounded in the principles of contextual and case-based learning. By presenting real-life problems related to the processing of coconut shell waste, the module enables students to connect abstract scientific concepts with authentic situations, thereby facilitating deeper conceptual understanding. In addition, the structured activities embedded in the module guide students through the processes of analyzing cases, interpreting data, and discussing solutions collaboratively, aligning with constructivist learning theory, which emphasizes active knowledge construction. The integration of scientific literacy indicators within each task also ensures that students systematically practice explaining phenomena, evaluating investigations, and interpreting evidence (Geraldine & Simmie, 2025). These design elements collectively contribute to more meaningful and organized learning experiences, which in turn lead to improved student learning outcomes.

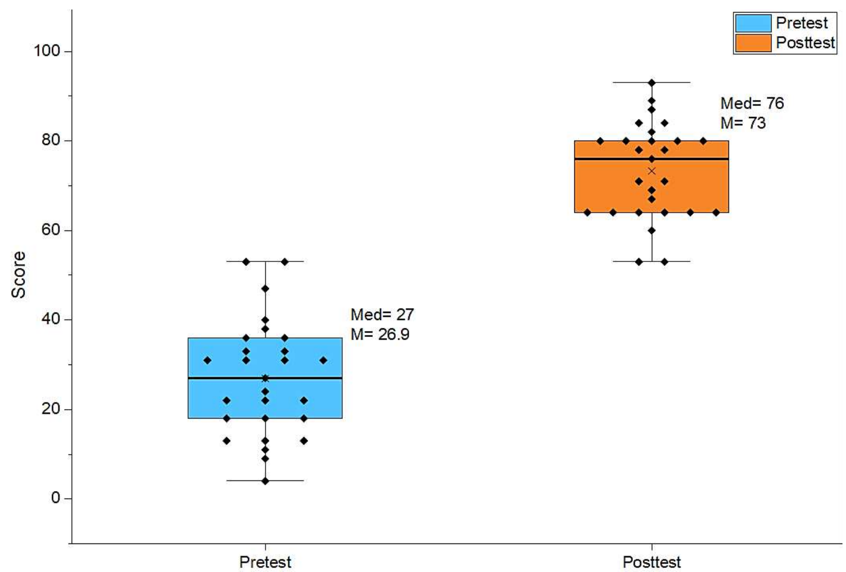

Figure 5. Box and whisker plot of pre-test vs. post-test score distributions

Figure 5 illustrates a box-and-whisker plot showing the distributional changes between pre-test and post-test scores for 27 students. The pre-test distribution was highly skewed with a median of 22 and a mean of 27.00, and had considerable variation (range: 4-53), indicating varying initial abilities. After the intervention, the post-test distribution shifted sharply to the right with a median of 78 and a mean of 73.40 (range: 53-93). The lack of interquartile range overlap between the two distributions clearly indicates a significant and consistent increase in scientific literacy scores, consistent with the results of a paired-sample t-test ($t(26) = 16.84$, $p < 0.001$). Student 7E-21 achieved a post-test score of 53, which appears to be an outlier at the lower end of the post-test distribution, and may require more targeted instruction.

Figure 6 illustrates N-gain per indicator, showing that the indicators "Explaining Phenomena Scientifically" and "Interpreting Data and Evidence Scientifically" both achieved an N-gain of 0.70, which is at the top of the High category. In comparison, the indicator "Evaluating and Designing Scientific Inquiry" recorded a moderate N-gain of 0.50, indicating that this more complex competency, which involves students formulating hypotheses, identifying and controlling variables, and designing procedures, was more difficult for students to learn during the module.

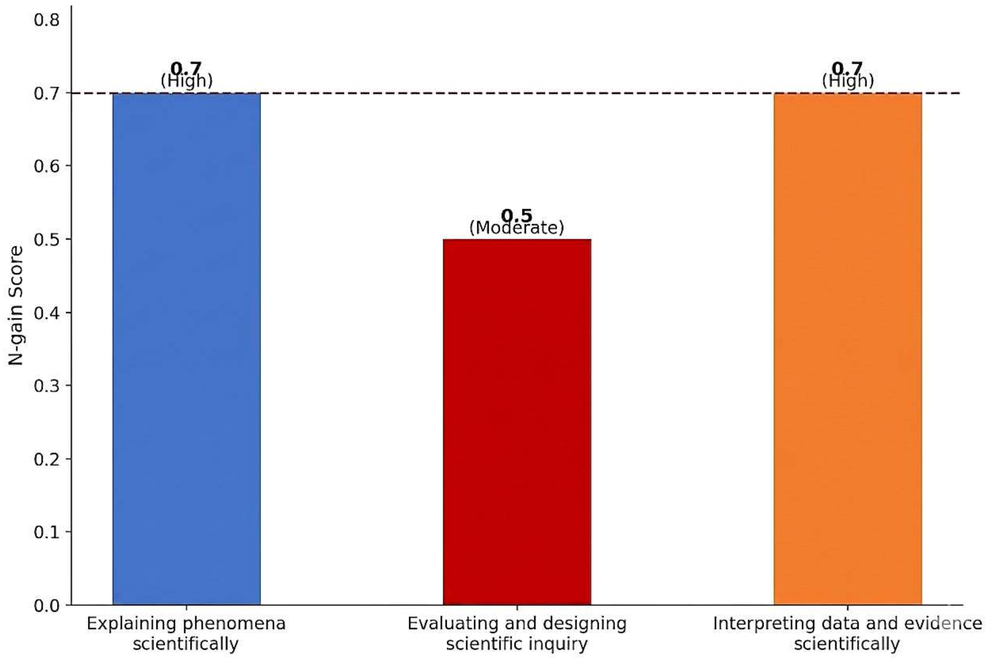

Figure 6. N-gain per scientific literacy indicator

Figure 7 illustrates the N-gain Bar Graph, showing the differences among the 27 students in their improvement. Of the 27 students, 12 achieved N-gain values in the High category (0.70 and above), 14 in the Medium category (0.30-0.69), and 1 student (7E-21) achieved an N-gain value of 0.30, at the lower end of the Medium category. This variation suggests the need for instructionally tailored follow-up and encourages future studies to use quasi-experimental designs to separate module effects from individual differences. This indicates that 100% of the

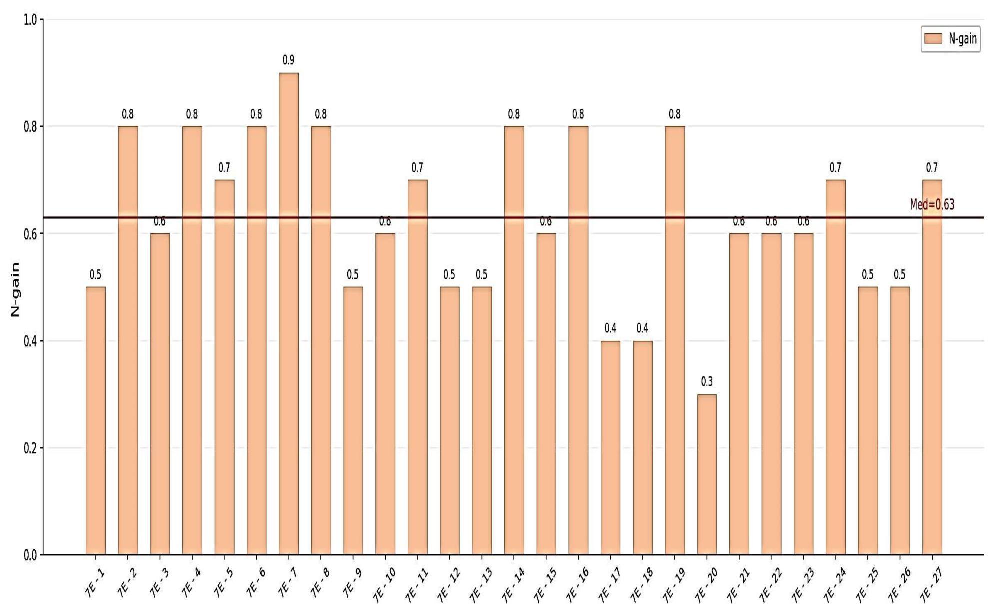

Figure 7. Individual n-gain scores per student (n = 27)

participants showed a positive shift in their literacy scores following the intervention (Wahyuni et al., 2025). The upward vertical shift in the coordinates reflects a substantial achievement gain, moving from a low-level mean (M = 27.00) to an advanced post-intervention mean (M = 73.40). Furthermore, the spatial distribution of these points aligns with the calculated N-gain of 0.60 and a median score of 0.63. The concentration of data in the upper middle quadrant confirms that the Case-Based Learning module, centered on coconut shell waste, effectively bridges the gap between theory and real-world application ($p < 0.001$).

The results of the student response questionnaire show that the module received an average score of 81%, which is excellent, indicating that it meets the criteria for readability, content suitability, and visual appeal. The attractive appearance received a score of 77% (good category), suggesting that students perceived the module's visual design as engaging and potentially motivating, thereby supporting a more enjoyable learning experience. These findings align with research by Alwadei & Mohsen (2023), which found that attractive visuals can increase students' focus and interest in learning the material.

In terms of material accessibility, students gave a score of 82% (very good), indicating that the material was presented in accordance with their cognitive development and did not overload them cognitively. These results support research by Putra, Ahmad, et al. (2023), which found that modules with systematic and contextual presentation of material can optimally improve student understanding. In addition, the aspect of language clarity received the highest score, namely 83% (very good), indicating that the language used in the module is communicative, clear, and appropriate for the learners' characteristics.

■ LIMITATION AND FUTURE RESEARCH

There are several limitations to this study that need to be clearly stated to facilitate the interpretation of the results. The study's internal validity is a major limitation. This study design was a single-group pretest-posttest without a control group. Although a paired-sample t-test showed a statistically significant increase in scientific literacy scores from 27.00 to 73.40 from pretest to posttest, this study design cannot claim that this increase was solely due to the CBL module. The lack of a control group prevents us from ruling out other explanations for the increase in scientific literacy, such as experiential effects (other classroom experiences during the intervention), maturational effects (the natural development of students' cognitive abilities), and testing effects (students becoming accustomed to the test format after the pretest). Consequently, the significant pretest-to-posttest increase observed reflects a correlation, not a causal claim, between the use of the CBL module and improvements in scientific literacy. This is an important limitation, given that the N-gain index, a popular measure for comparing learning interventions, does not account for factors that affect internal validity.

A second limitation relates to sample size and generalizability. The sample consisted of 27 students from one seventh-grade class at SMPN 2 Panti, selected through purposive sampling. This limits the generalizability of the study findings to other student groups, other types of schools, or different regions. Furthermore, the study was conducted over only one semester, so the effects on students' scientific literacy were not examined over time. This study could be improved by using a quasi-experimental model with an unequal control group, which would allow for stronger causal claims. Specifically, future research is recommended to use the CBL module in the experimental class. In contrast, an unequal control class receives conventional instruction, with pre-test scores as a covariate in an analysis of covariance (ANCOVA) to enhance internal validity. Sampling from multiple schools, a longer follow-up period (including a delayed posttest), and longitudinal assessment of scientific literacy would also strengthen the validity and generalizability of this study and improve the instrument's reliability.

CONCLUSION

The case-based learning module on coconut shell waste processing demonstrated the potential to meet the feasibility criteria for use as a science learning resource in terms of validity, practicality, and effectiveness. The validation results showed an average score of **92%**, categorized as **very valid**, indicating that the module meets high standards for instructional material development in content, local context integration, language use, scientific literacy indicators, and graphic design. In terms of practicality, the module achieved an average score of **87%**, which is categorized as very practical, indicating that it is easy to use and effectively supports learning activities aimed at improving scientific literacy. Meanwhile, the effectiveness aspect was indicated by a significant improvement in students' scientific literacy, with an N-gain of 0.6 in the moderate category and two scientific literacy indicators reaching the high category. This finding was further supported by very positive student responses regarding the clarity of the material, language, and visual appearance of the module, confirming that the case-based learning module is effective and well accepted as a science learning resource.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the preparation of his manuscript, the author used Grammarly to support language refinement and proofreading. The authors have carefully reviewed and revised the output generated by this tool and take full responsibility for the content of the published article.

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