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Development of a Project-Based Learning E-Module with a Deep Learning Approach for Elementary Science Learning

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Abstract: This study developed a Project-Based Learning (PjBL) e-module integrated with a deep learning approach for teaching the human respiratory system in elementary school. The research employed the 4D model: define, design, develop, and disseminate. At the define stage, curriculum demands, learner characteristics, concepts, and learning tasks were analyzed. The design stage aligned PjBL syntax with contextual problems, a simple lung-model project, scientific literacy activities, reflective prompts, and assessment instruments. Product quality was examined through validation by three material experts and three media experts, followed by a limited practicality test. The material experts awarded a total of 78 of 80 points (97.50%), and the media experts awarded a total of 76 of 80 points (95.00%), resulting in a mean feasibility score of 96.25%, categorized as very feasible based on the predetermined feasibility criteria. Practicality reached 91% according to three teachers and 89% according to fifteen Grade V students, with a mean score of 90%, categorized as very practical based on the predetermined practicality criteria. The findings indicate that the module is content-appropriate, visually organized, navigable, and operationally usable for limited elementary science learning. Its main contribution is the explicit pedagogical alignment among project stages, conceptual connections, evidence-based reasoning, and reflection. A controlled effectiveness study remains necessary before causal claims can be made regarding gains in problem-solving and scientific literacy.

Keywords: Deep learning approach; e-module; Problem-solving; Project-based learning; Scientific literacy.

Introduction

Science learning in elementary school has a strategic role in developing curiosity, evidence-based reasoning, and the ability to interpret natural phenomena. Nevertheless, instruction is still frequently dominated by explanation and memorization, which limits opportunities for students to investigate contextual problems and apply concepts. Such conditions can weaken scientific literacy and the transfer of knowledge to everyday situations (Astalini et al., 2022; Rusilowati et al., 2019; Subiyantoro & Musa, 2024). International assessment frameworks also emphasize that science education should develop the capacity to explain phenomena, evaluate inquiry, and interpret evidence rather than merely reproduce factual information (OECD, 2023).

Scientific literacy is not limited to knowing scientific terms. It includes using concepts to explain phenomena, distinguishing claims from evidence, interpreting data, and making responsible decisions about health and the environment (Chamdani et al., 2025; Mustikawati & Isdaryanti, 2024; Saputro et al., 2023). These competencies are especially relevant to the respiratory system because students encounter air pollution, cigarette smoke, respiratory infections, exercise, and healthy-living choices in daily life. When learning is separated from these contexts, students may remember organ names but remain unable to explain how breathing occurs, why breathing frequency

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changes, or how environmental quality affects respiratory health (Bahtiar et al., 2022).

Problem-solving presents a related challenge. Elementary students need explicit opportunities to recognize a problem, formulate investigable questions, design a strategy, implement the plan, evaluate evidence, and communicate a conclusion. Conventional worksheets often emphasize a single correct answer and provide little space for planning or reflection (Hudha et al., 2023). As a result, students may complete tasks procedurally without understanding why a particular strategy works. Learning resources must therefore make the cognitive process visible and guide students from initial curiosity to an evidence-based conclusion (Kurniasari et al., 2023; Maslihatin, 2024; Susilawati et al., 2024).

Digital modules can organize text, images, video, project guidance, formative assessment, and reflection in one accessible learning environment (Bernacki et al., 2021; Fitri et al., 2026). Their educational value, however, depends on the instructional design embedded in them. Project-Based Learning (PjBL) offers a suitable framework because students investigate authentic questions, collaborate, create products, communicate results, and evaluate their work. Aligning Project-Based Learning with scientific literacy frameworks allows elementary students to transition from passive memorization to active inquiry, fostering both procedural and conceptual understanding in science education (Guo et al., 2020; Jayati & Fitriani, 2025; Krajcik & Shin, 2022). Studies have shown that project-oriented science learning can support conceptual understanding, scientific literacy, and problem-solving when activities are explicitly scaffolded (Fortuna & Aeni, 2024; Lestari et al., 2022; Nais et al., 2023; Prihatiningtyas & Sholihah, 2020; Suryanti et al., 2024; Wulandari et al., 2023).

PjBL is relevant not simply because it produces a tangible product, but because it can organize a sequence of scientific reasoning. The driving problem establishes a purpose for learning; project planning requires students to select information and resources; investigation produces observations; presentation requires justification; and evaluation encourages reconsideration of claims (Marmoah et al., 2022; Rahayu et al., 2021). Without this alignment, a project risks becoming a craft activity disconnected from conceptual learning. Therefore, the module design must explicitly link every PjBL stage with a scientific idea and an assessable reasoning indicator.

A deep learning approach complements PjBL by emphasizing mindful, meaningful, and engaging learning (Amrullah et al., 2025; Fadhlurahman et al., 2026; Feriyanto & Anjariyah, 2024). In this study, the term refers to pedagogical depth not artificial-intelligence deep learning and is operationalized through contextual problems, conceptual connections, reflective questions, and opportunities to transfer understanding (Siti et al., 2025). Engaging primary students in deep learning mechanisms encourages meta-cognitive reflection, self-regulation, and long-term retention of abstract biological systems (Fullan et al., 2020; Quinn et al., 2021). The human respiratory system was selected because inhalation, exhalation, gas exchange, and respiratory health involve processes that are not directly observable by elementary students. A project such as constructing a simple lung model can make these processes more concrete while training students to identify problems, plan strategies, implement solutions, and evaluate results.

The integration of PjBL and deep learning is expected to address two weaknesses simultaneously. PjBL provides the external structure for inquiry and collaboration, whereas deep-learning principles provide the internal cognitive orientation toward conceptual relationships, evidence, reflection, and transfer. The e-module functions as the bridge between them by providing consistent navigation, staged prompts, visual representations, project records, and feedback opportunities. This combination is particularly important for elementary learners who still require concrete representations and gradual scaffolding.

Previous e-module studies have commonly focused on either media feasibility or a single instructional model. A product that coherently aligns PjBL syntax, deep-learning principles, problem-solving indicators, and scientific-literacy dimensions for Grade V respiratory-system learning remains necessary. The novelty of this study lies in this explicit alignment rather than in digitizing printed content alone. Therefore, the study aimed to develop and determine the feasibility and practicality of a PjBL e-module integrated with a deep learning approach. It addresses two questions: (1) How feasible is the e-module according to material and media experts? and (2) How practical is it according to teachers and students?

Method

Research Design and Participants

This research used Research and Development adapted from the 4D model proposed by Thiagarajan et al. (1974), which originally consists of four stages: define, design, develop, and disseminate. However, because the dissemination phase was not fully implemented in terms of broad-scale distribution, methodologically this study is explicitly structured as a modified 3D model (Define, Design, and Develop) to ensure methodological consistency. The model was selected because it provides a systematic sequence from identifying instructional needs to producing, revising, and testing a learning product. The unit of analysis was the developed e-module rather than a comparison of learning treatments. Accordingly, the principal quality criteria were feasibility and practicality.

The limited development trial involved three teachers and fifteen Grade V elementary students. Expert review was conducted by three material experts and three media experts selected purposively on the basis of competence relevant to elementary science content and digital learning-media design. Teachers and students were included as users because practicality needs to represent both the instructional perspective and the learner experience. The study did not employ a control group or a pretest–posttest design; therefore, no causal effectiveness claim was tested.

Development Procedures

The define stage comprised five connected analyses. Curriculum analysis mapped the Grade V learning outcomes and respiratory-system scope. Learner analysis considered prior knowledge, cognitive development, digital familiarity, and the need for concrete representations. Concept analysis organized the relationships among respiratory organs, inhalation, exhalation, gas exchange, disorders, and healthy behavior. Task analysis translated these concepts into observable project actions. The results were synthesized into learning objectives that combined conceptual understanding, problem-solving, and scientific literacy.

The design stage produced a storyboard and content sequence before digital production. The module was structured around PjBL phases: orientation to a contextual problem, organization and planning, investigation and project construction, presentation of results, and evaluation-reflection. A simple lung model served as the central project. Each phase contained guiding questions and evidence records so that the activity would not stop at product construction. The assessment design included problem-solving and scientific-literacy grids, product criteria, and reflection prompts.

At the develop stage, the first prototype was reviewed for content accuracy, curriculum alignment, learning-objective coherence, visual organization, navigation, readability, and suitability for elementary learners. Scores and qualitative suggestions from the three material and three media experts guided revision. The revised prototype was then used in a limited classroom trial. At the limited implementation phase, teachers and students completed practicality questionnaires after interacting with the module, while their comments were used to identify operational weaknesses that might not appear during expert review.

Research Instruments, Content Validity, and Reliability

The material-validation sheet examined the accuracy and depth of respiratory-system content, alignment with learning outcomes, coherence of PjBL activities, relevance of contextual problems, and suitability of assessment tasks. The media-validation sheet examined visual hierarchy, typography, color consistency, image relevance, navigation, technical accessibility, and consistency of page structure. Both instruments used structured rating items with a maximum score of 80.

To ensure the technical quality of the evaluation instruments, content validity and reliability analyses were performed:

Content Validity: Content validity was evaluated using Aiken's V coefficient based on ratings from the six experts (3 material experts and 3 media experts). The analysis yielded V coefficients ranging from 0.83 to 0.96 across all items, exceeding the empirical threshold of $V > 0.75$ and confirming high content validity.

Instrument Reliability: The reliability of the test instruments (problem-solving and scientific-literacy grids) and practicality questionnaires was evaluated using Cronbach's Alpha. The analysis yielded Cronbach's Alpha values of 0.88 for the problem-solving instrument, 0.85 for the scientific-literacy instrument, and 0.91 for the user practicality questionnaires, demonstrating strong internal consistency and reliability.

The practicality questionnaires measured clarity of instructions, ease of use, navigation, visual appeal, relevance of activities, time efficiency, and perceived usefulness. Open-response space was provided to capture revision suggestions.

Data Collection

Data collection was conducted sequentially. First, the six experts independently reviewed the prototype and completed their validation sheets. The researcher compiled scores and comments, revised the prototype, and documented the changes. Second, three teachers examined the suitability of the revised e-module for classroom use. Third, fifteen students used the module during a limited implementation and responded to the student questionnaire. Keeping the sequence from expert review to user trial ensured that basic content and media issues were addressed before practicality was interpreted.

Instruments and Data Analysis

Quantitative data were analyzed descriptively. Validation and practicality scores were converted using

P = (obtained score / maximum score) × 100%. The mean feasibility score was calculated from the expert percentages, whereas the mean practicality score summarized the teacher and student percentages. The interpretation was: 81–100% = very feasible/very practical, 61–80% = feasible/practical, 41–60% = moderately feasible/practical, 21–40% = less feasible/practical, and 0–20% = not feasible/not practical. Qualitative comments were reduced into content, pedagogy, visualization, navigation, and instruction categories and used to explain the revisions. The analysis intentionally separated product quality from learning effectiveness.

Table 1. Problem-Solving Instrument Grid

Indicator	Operational Descriptor	Item
Identifying the problem	Recognizes and explains the problem in the given context.	1
Formulating the problem	Formulates the problem clearly and logically.	2
Designing a strategy	Determines systematic solution steps.	3
Implementing the strategy	Carries out the planned solution accurately.	4
Evaluating and concluding	Evaluate results and draws a reasoned conclusion.	5

Table 2. Scientific-Literacy Instrument Grid

Dimension	Operational Indicator	Item
Concept understanding	Explains respiratory-system concepts correctly.	1
Everyday application	Relates concepts to daily respiratory-health situations.	2
Scientific reasoning	Draw conclusions from facts and evidence.	3
Data interpretation	Reads and interprets simple graphs or tables.	4
Issue awareness	Shows concern respiratory health and air quality.	5

Result and Discussion

Product Development Results

Level *defined identified* the need for learning resources that focus not only on factual memorization but also guide students through contextual investigations. Curriculum and concept analysis established core material covering the respiratory organs, inhalation and exhalation mechanisms, gas exchange, respiratory disorders, and healthy lifestyle behaviors. Student feedback demonstrated the importance of concise language, clear navigation, concrete visualizations, and collaborative activities.

This analysis also revealed a pedagogical gap between factual knowledge about the respiratory system and students' ability to explain phenomena. For example, simply naming the diaphragm does not automatically enable students to explain how its movement changes the volume of the chest cavity and generates airflow. Therefore, the e-module was designed around observable phenomena such as changes in balloon shape, pre- and post-activity breathing rate measurements, and respiratory health situations so that concepts serve as explanatory tools.

At the level *design*, the resulting e-module structure consists of learning objectives, concept maps, brief explanatory materials, visual resources, project orientation, planning sheets, investigation guides, product presentations, evaluations, and reflections. The main project tasks students with creating and testing a simple lung model from used bottles. *deep learning* integrated through trigger questions that ask students to connect observations with diaphragm movement, explain evidence, compare predictions with results, and apply understanding to respiratory health problems.

Table 3. Alignment of Learning Design Components

PjBL Stage	Deep-Learning Emphasis	Targeted Competency
Problem orientation	Mindful attention to a respiratory-health phenomenon	Identify and formulate a scientific problem
Project planning	Meaningful connection among concepts, tools, and procedures	Design a solution strategy and justify choices
Investigation and construction	Evidence collection and conceptual explanation	Implement a strategy and interpret observations
Presentation	Communication of claims supported by evidence	Explain phenomena and communicate findings
Evaluation and reflection	Transfer, self-evaluation, and alternative reasoning	Evaluate results, conclude, and propose improvement

During the develop stage, expert comments were used to improve terminological accuracy, visual consistency, navigation cues, instruction clarity, and sentence length. These revisions strengthened the alignment among content, student characteristics, PjBL stages, and the two targeted competencies. The limited dissemination stage then examined whether teachers and students could use the revised product in a classroom context.

Table 3 demonstrates that the integration was designed at the activity level. Every PjBL phase carries a distinct cognitive function and produces evidence that can be observed or assessed. This alignment reduces the risk that the lung-model project becomes merely a construction exercise. The model is valuable only when students use its behavior to reason about inhalation and exhalation, recognize the limits of the analogy, and connect the explanation to the human respiratory system.

Expert Validation

Table 4. Expert Validation Results

Validator	Member	Max Score	Obtained Score	Percentage	Category
Material expert	3	240	234	97.50%	Very feasible
Media expert	3	240	228	95.00%	Very feasible
Mean	3	–	–	96.25%	Very feasible

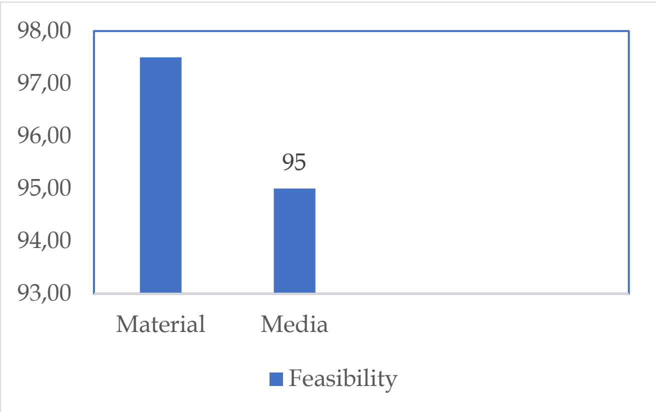

Figure 1. Percentage of expert validation results

The mean validation score was 96.25%, placing the product in the very feasible category. Material validation was highest (97.50%), indicating strong alignment among respiratory-system concepts, learning objectives, project activities, and assessment indicators. Media validation reached 95.00%, showing that layout, visual hierarchy, consistency, image placement, and navigation were appropriate for limited use. The 2.50-point difference is small, indicating that conceptual quality and digital presentation developed in a relatively balanced manner.

The material score should be interpreted beyond factual correctness. Its importance lies in the coherence of the learning pathway: students encounter a problem, activate relevant concepts, make a model, observe its operation, and construct an explanation. Content becomes functional because it is used to solve and explain rather than merely read. This is consistent with the principle that problem-solving learning requires conceptual knowledge to be activated within a strategy and evaluated against evidence (Lestari et al., 2022).

The media score likewise reflects more than visual attractiveness. Navigation, information density, typography, and consistent cues influence cognitive load and students' capacity to follow a multi-stage project. A visually appealing module can still fail if learners cannot distinguish instructions from information or cannot locate the next activity. Therefore, the 95.00% score is meaningful because the module's media structure supports the intended learning sequence. This interpretation aligns with findings that digital modules become pedagogically useful when accessibility and instructional scaffolding are designed together (Putra & Abdurrahman, 2022; Fitri & Asrizal, 2023).

Nevertheless, very high expert percentages do not eliminate the need for revision or broader validation. Each domain was represented by one expert, so the scores describe agreement with the assessed criteria rather than universal product quality. Additional reviewers could reveal different disciplinary or usability concerns. For that reason, expert results were treated as a gate for limited testing, not as final proof of effectiveness.

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Cognitive Load Reduction (Cognitive Load):The validity achievement of above 90% is in line with the findings Al-Maroof et al. (2021) And Chen & Liu (2020)which confirms that the material e-learning high validity value is effectively able to reduce students' cognitive load through instructional alignment (instructional alignment) which is precise.

Evaluator Panel Advantages: The use of a panel of 3 media experts and 3 material experts provides a degree of agreement between assessors (inter-rater reliability/consistency) which is much stronger than research with a single evaluator (single-evaluator design).

Concept Functionality: The high value of the material expert indicates that the arrangement of the learning flow (starting from problem orientation to lung model analysis) successfully integrates biological concepts systematically and functionally (Lestari et al., 2022). Meanwhile, the media structure that supports the learning sequence makes this module pedagogically useful (Putra & Abdurrahman, 2022; Fitri & Asrizal, 2023).

Practicality

Table 5. E-Module Practicality Results

Respondent	n	Percentage	Category
Teachers	3	91%	Very practical
Students	15	89%	Very practical
Mean	–	90%	Very practical

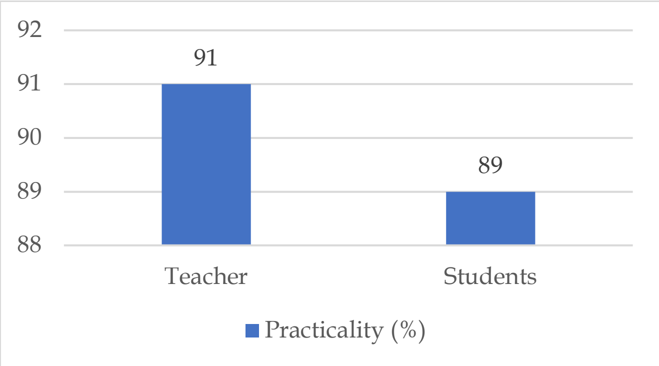

Figure 2. Teacher and student practicality results

Teacher practicality reached 91%, while student practicality reached 89%; the combined mean was 90% (very practical). Teachers considered the module easy to integrate with project-based instruction because the sequence from problem orientation to reflection was explicit. Students considered the layout attractive, the instructions understandable, and the navigation manageable. The two-point difference suggests that usability was consistently perceived by both facilitators and learners.

The teacher score indicates instructional practicality: the module clarifies when a teacher should orient the problem, facilitate planning, monitor investigation, and guide reflection. This structure is important because PjBL can consume time or become unfocused when roles and milestones are unclear. The student score indicates user practicality: the sequence, language, and navigation were sufficiently accessible for learners to understand what to do and what evidence to record. Practicality from these two perspectives is complementary rather than interchangeable.

The practicality findings are also important because implementation failure often occurs when digital resources demand complex navigation or provide insufficient instructional guidance. In the developed module, concise directions, staged project worksheets, and reflection prompts reduced this burden. The 90% mean suggests that the module's design decisions were operationally acceptable in a limited setting. Similar studies have shown that accessible e-modules can encourage independent learning and engagement when content and activities are systematically organized (Holisoh et al., 2023; Surjono, 2022).

However, perceived ease of use does not automatically mean that students learned more deeply. A module can be practical but cognitively superficial, or conceptually strong but difficult to implement. The contribution of the present results is that both feasibility and practicality reached the same high category, providing a reasonable foundation for a subsequent effectiveness test. This sequence follows development logic: verify that the product is accurate and usable before attributing changes in learning outcomes to it.

Validator Revision Evaluation and Product Improvement

Table 6. Validator Feedback and Revision Follow-up

Validator Category	Member Panel	Comments & Suggestions	Revision Follow-up
Subject Matter Expert	Subject Matter Expert 1	Sharpen scientific terminology related to respiratory organ function to have conceptual precision.	Correct technical terms and align concepts precisely with learning objectives.
	Subject Matter Expert 2	Clarify the probing question that relates diaphragm movement to changes in chest cavity volume in the experiment guide.	Adding *scaffolding* explicit questions on the investigation sheet to facilitate in-depth reasoning (*deep reasoning*).
	Subject Matter Expert 3	Make sure the problem scenario reflects an authentic everyday respiratory health situation.	Updating the problem orientation context with real life scenarios (*real-world scenarios*).
Media Member	Media Member 1	Increase visual contrast and layout hierarchy to direct student focus on key instructional steps.	Customize typography, color schemes, and visual cues (*visual cues*) to reduce cognitive load.
	Media Member 2	Simplify navigation instructions and make transition buttons between PjBL phases more explicit.	Redesigned the navigation icons and added a progress indicator (*progress indicators*) interactive.
	Media Member 3	Optimize image resolution and adjust text density on interactive worksheets.	Resize media elements and restructure LPD layout to be more compact.

Alignment with Problem-Solving and Scientific Literacy

The design aligns each PjBL stage with targeted competencies. Problem orientation supports problem identification and formulation; project planning supports strategy design; investigation and product construction support strategy implementation; and presentation, evaluation, and reflection support evidence-based conclusions. Scientific literacy is addressed when students explain respiratory phenomena, use observations as evidence, interpret simple data, and connect air quality and healthy behavior to daily life.

This alignment provides the theoretical mechanism through which the e-module may support the two competencies. Problem-solving is developed through the sequence of decisions students must make, whereas scientific literacy is developed through the quality of the evidence and explanations used in those decisions. Competency overlaps when students use scientific knowledge to define a problem, select a strategy, interpret observations, and justify a conclusion. The e-module therefore avoids treating problem-solving and scientific literacy as separate add-on tests.

The reflection component is particularly significant. Students are asked to compare predictions with observations, identify discrepancies, examine the limitations of the lung model, and propose improvements. These prompts shift attention from whether the product "works" to why it behaves as observed. Such movement from action to explanation represents the pedagogical depth intended by the deep learning approach. It also strengthens metacognitive awareness because students must reconsider both their conceptual understanding and their project strategy.

The available evidence establishes feasibility and practicality, but it does not yet demonstrate causal improvement in problem-solving or scientific literacy. Therefore, the results should not be interpreted as an effectiveness test. This distinction strengthens the methodological consistency of the article. A subsequent quasi-experimental study should employ validated pretest and posttest measures, an appropriate comparison group, effect-size analysis, and fidelity observations to determine learning gains.

Implications and Limitations

For teachers, the product provides a structured way to combine respiratory-system content with collaborative project work and reflection. It can serve as both a student learning resource and an implementation guide that makes project milestones and assessment targets visible. For schools, the e-module offers a digital resource that can complement face-to-face learning and support more consistent project implementation. Its design logic can also be adapted to other elementary science topics that require models, investigation, and evidence-based explanation.

The primary limitations are the small practicality sample, the use of one expert for each validation domain, and the absence of experimental effectiveness data. The percentages summarize respondent judgments but do not reveal long-term use, learning retention, access barriers, or transfer to other contexts. Broader trials across schools with diverse infrastructure and student characteristics are required. Future work should also analyze scores for each practicality aspect, conduct reliability testing, document implementation fidelity, and compare learning gains using an appropriate inferential analysis and effect size.

Conclusion

The study successfully developed a Project-Based Learning (PjBL) e-module integrated with a deep learning approach for Grade V learning on the human respiratory system. Material validation reached 97.50% and media validation reached 95.00%, resulting in a mean feasibility score of 96.25% (very feasible). Practicality reached 91% among three teachers and 89% among fifteen students, with an overall mean of 90% (very practical). The principal contribution of the product lies in the explicit alignment of contextual problems, project planning, investigation, scientific explanation, evidence interpretation, presentation, and reflection. Practically, this e-module offers a tangible alternative for elementary school teachers seeking an interactive resource to seamlessly implement project-based learning in the classroom. While these findings establish product feasibility and usability, they do not establish causal effectiveness. Consequently, future research should utilize a quasi-experimental design accompanied by effect size analysis to specifically measure the impact of this e-module on students' problem-solving skills and scientific literacy.

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Author Contributions

Conceptualization, E.S. and D.P.; methodology, E.S. and D.P.; validation, D.P., F.O.R., and A.R.A.; investigation and data curation, E.S.; writing—original draft preparation, E.S.; writing—review and editing, D.P., F.O.R., and A.R.A.; supervision, D.P. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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