Journal of Educational Sciences
Journal homepage: https://jes.ejournal.unri.ac.id/index.php/JES
P-ISSN 2581-1657
E-ISSN 2581-2203

Development of PjBL E-Modules with a Deep Learning Approach for Problem Solving and Scientific Literacy

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ARTICLE INFO

Article history:

Received: 30 Dec 2025
Revised: 09 March 2026
Accepted: 25 March 2026
Published online: 05 April 2026

Keywords:

E-Module,
Deep Learning,
Problem Solving,
Project-Based Learning,
Respiratory System,
Scientific Literacy

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Article Doi:

https://doi.org/10.31258/jes.10.4.p.13-27

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A B S T R A C T

The low scientific literacy and problem-solving skills of elementary school students indicate the need for innovative learning media that are meaningful, contextual, and appropriate to student characteristics. One alternative solution is the development of Project-Based Learning (PjBL)-based e-modules integrated with a deep learning approach. This study aims to develop interactive e-modules on the human respiratory system that can increase student learning engagement, reflective thinking, and in-depth understanding. The development model used is 4D (Define, Design, Develop, Disseminate). The Define stage is carried out by analyzing the curriculum and student needs. The Design stage produces an e-module design with a project structure that integrates critical thinking activities. The Develop stage involves validation by material experts (score 78/80), media (76/80), and language (75/80) with the category "very feasible". The Disseminate stage is carried out through a practicality test that shows very positive results, with an average score of 91% from teachers and 89% from students. The e-module is considered interesting, communicative, easy to use, and encourages independent learning and increased scientific literacy. The results of this study indicate that the developed e-module is feasible and practical for use in science learning in elementary schools.

1. Introduction

Natural Science (IPA) learning in elementary schools plays a fundamental role in developing students' scientific thinking, curiosity, and ability to understand natural phenomena critically. At the primary level, science education lays the foundation for inquiry skills, logical reasoning, and early problem-solving abilities. However, classroom practice is still frequently dominated by teacher-centered instruction and memorization-oriented activities. Students are often required to recall definitions

and formulas without being given sufficient opportunities to explore, investigate, and relate concepts to real-life situations. This condition results in fragmented understanding and limited knowledge transfer. As highlighted by Rusilowati et al. (2019), such instructional patterns hinder the development of scientific literacy and analytical reasoning. Development studies published in the *Journal of Educational Sciences* (JES) also emphasize the urgency of instructional innovation to shift learning environments from passive to inquiry-oriented approaches. For example, Wahyuni et al. (2025) demonstrated that project-based e-modules significantly foster creative thinking and digital literacy skills in science classrooms. Therefore, improving elementary science instruction requires both pedagogical reform and the development of innovative learning media.

Concerns regarding science learning quality are further reinforced by international assessment results. Indonesian students' performance in the Programme for International Student Assessment (PISA) remains below the international average, reflecting systemic challenges in promoting reasoning-based and contextual understanding. The OECD (2019) stresses that science education should prioritize real-world problem-solving, critical interpretation of data, and conceptual application rather than rote memorization. Consistent findings appear in module development research. Rosiana et al. (2023) reported that structured inquiry-based e-modules improved students' critical thinking skills, while Hasibuan et al. (2025) found that interactive discovery-based e-modules enhanced conceptual mastery in biology topics. These studies indicate that digital modules can serve as bridges between curriculum expectations and classroom realities, particularly when designed with strong inquiry frameworks. Thus, strengthening scientific literacy requires integrating structured pedagogical models within accessible digital media.

One instructional model that aligns with these demands is Project-Based Learning (PjBL). PjBL emphasizes investigation, collaboration, and authentic problem-solving through contextual projects. Rather than passively receiving information, students actively construct knowledge by producing tangible outputs and reflecting on their learning processes. Research within JES supports the effectiveness of project-oriented instruction. Wahyuni et al. (2025) reported that PjBL-based e-modules integrated with green pedagogy significantly improved students' creative and digital competencies. Similarly, Sari et al. (2026) found that project-based modules enhanced 21st-century skills, including collaboration and critical thinking. Lestari et al. (2022) further emphasized that project-based science instruction strengthens analytical reasoning and contextual understanding. These findings confirm that PjBL provides a strong pedagogical foundation for developing meaningful science learning experiences.

In addition to pedagogical innovation, technological integration plays an important role in supporting conceptual understanding, especially for abstract scientific topics. Augmented Reality (AR) has been widely explored as a tool to visualize internal biological and physical processes. Several JES publications demonstrate the effectiveness of AR-based media. Khusnunnisa and Andriani (2025) developed AR-assisted multimedia for human sensory system materials and reported improved conceptual clarity. Septiani et al. (2025) showed that AR-integrated media

enhanced students' learning outcomes in atomic theory. Zahro et al. (2024) and Febriyanti and Andriani (2025) similarly found that AR-based instructional media increased engagement and comprehension in elementary science topics. These studies indicate that AR can transform abstract content into interactive visual experiences. However, many AR developments emphasize visualization and effectiveness testing, while fewer integrate comprehensive pedagogical frameworks such as PjBL and deep learning. This gap highlights the need to combine technological tools with structured instructional design.

E-modules offer a flexible platform for integrating pedagogical models and technological enhancements into a coherent learning system. Digital modules can incorporate multimedia elements, structured project instructions, reflective prompts, and formative assessments within a systematic format. Safitri and Andromeda (2025) demonstrated that problem-based e-modules integrated with STEAM approaches improved students' motivation and learning outcomes. Hafni et al. (2025) also reported that PBL-based e-modules increased motivation and academic achievement in physics learning. Furthermore, Abdurrahman et al. (2025) emphasized the importance of usability and user experience evaluation to ensure practicality and implementation feasibility. These findings consistently support the integration of pedagogy and technology in digital module development.

To avoid superficial engagement with digital content, the deep learning approach serves as an essential theoretical foundation. Deep learning promotes reflective thinking, conceptual connections, and meaningful knowledge transfer beyond memorization. Syahrir et al. (2025) showed that AR-based modules combined with structured inquiry enhanced conceptual depth in IPAS themes. Zulaika et al. (2024) similarly found that AR-assisted learning cycles improved visual-spatial intelligence and conceptual reasoning. These studies suggest that digital innovation must be supported by cognitive scaffolding strategies such as reflective questioning, contextual analysis, and structured inquiry stages. Integrating PjBL with deep learning principles within an e-module ensures that students actively construct understanding while engaging in authentic projects.

The human respiratory system was selected as the focus of this development because it represents a foundational yet abstract topic in elementary science. Processes such as inhalation, exhalation, and gas exchange are difficult to visualize without concrete representation. Prior AR-based developments on sensory systems and plant systems (Khusnunnisa & Andriani, 2025; Zahro et al., 2024) demonstrate that visualization significantly aids comprehension of internal body mechanisms. However, structured project integration within such developments remains limited. By embedding project tasks such as constructing lung models and analyzing breathing patterns within a digital module, abstract biological processes can become experiential and contextual. This strategy aligns with inquiry-based AR research while strengthening pedagogical coherence through PjBL and deep learning integration.

Based on this background, this research aims to develop a Project-Based Learning-based e-module integrated with a deep learning approach on the human respiratory

system. This development responds to three major scholarly trends identified in JES publications: digital module innovation, AR-enhanced visualization, and project-based pedagogy. Unlike previous studies that emphasize either technological visualization or learning outcome effectiveness alone, this research focuses on producing a pedagogically integrated product evaluated through validity and practicality measures. The ultimate goal is to create a structured, implementable, and theoretically grounded instructional medium that bridges technology, pedagogy, and cognitive engagement in a cohesive framework for elementary science learning.

2. Methodology

This research is a Research and Development (R&D) study based on the 4D development model (Define, Design, Develop, Disseminate) developed by Thiagarajan, Semmel, and Semmel (1974). This model was used because it can produce systematic and valid learning products for implementation in the classroom. The Define stage aims to analyze needs, including curriculum analysis, student characteristics, and initial identification of low scientific literacy and problem-solving skills. The Design stage includes designing the e-module using a Project-Based Learning (PjBL) approach and integrating deep learning principles, as well as developing research instruments such as validation sheets, practicality questionnaires, and student ability tests.

The Develop stage is conducted through validation by material, media, and language experts. Each validator assesses aspects of content suitability, readability, media presentation, and suitability to the characteristics of elementary school students. The Disseminate stage involves practicality testing on teachers and students to obtain empirical data on the feasibility of implementing the e-module in the learning process. The instruments used in this study included a validation sheet, a practicality questionnaire, and a test to measure students' problem-solving abilities and scientific literacy. These instruments were developed based on relevant indicators and validated before use. The following is a breakdown of the problem-solving ability instruments used in this study:

Table 1. Problem Solving Ability Instrument Grid

No	Indicators	Assessment Descriptors	Question Number
1	Identifying the problem	Students are able to recognize and explain problems from the given context.	1
2	Formulating the problem	Students are able to formulate problems using clear and logical sentences.	2
3	Designing a solution strategy	Students are able to determine and design steps to solve problems.	3
4	Implementing the strategy	Students are able to implement solution steps systematically and accurately.	4
5	Evaluating and drawing conclusions	Students are able to evaluate results and conclude the solutions implemented.	5

In addition to problem-solving skills, scientific literacy aspects are also measured using an instrument developed from OECD indicators and Chiappetta et al. (1991). Before presenting Table 2, it is necessary to explain the design of the instrument used to measure scientific literacy. The scientific literacy instrument in this study was developed based on several key dimensions that reflect students' abilities to understand scientific concepts, apply this knowledge in everyday life, and use scientific reasoning to analyze problems. In addition, the instrument is also designed to assess students' ability to interpret scientific data and demonstrate awareness of issues related to health, particularly respiratory health.

Each dimension of scientific literacy is operationalized into specific assessment indicators that can be measured through the prepared question items. Through these indicators, the assessment does not only focus on conceptual understanding, but also includes critical thinking skills, data analysis abilities, and awareness of scientific issues in the surrounding environment. The details of the dimensions, assessment indicators, and question numbers used in the scientific literacy instrument are presented in Table 2 below.

Table 2. Scientific Literacy Instrument Outline

No	Dimensions of Scientific Literacy	Assessment Indicators	Question Number
1	Understanding of scientific concepts	Students are able to explain the concept of the respiratory system correctly and simply.	1
2	Application of concepts in everyday life	Students are able to relate scientific concepts to real-world situations in their environment.	2
3	Scientific reasoning and thinking	Students are able to draw conclusions based on available facts and data.	3
4	Interpretation of scientific data	Students are able to read and interpret presented graphs/tables.	4
5	Awareness of scientific issues	Students demonstrate concern for the importance of maintaining respiratory health.	5

3. Results and Discussion

Result

This research resulted in a science e-module for elementary school students on the human respiratory system, developed using a 4D model and Project-Based Learning integrated with a deep learning approach. The e-module was validated by subject matter experts, media experts, and language experts, and its practicality was tested by teachers and students. The following are the results of each development stage.

Expert Validation Results

The validation process was conducted by three experts consisting of a subject matter expert, a media expert, and a language expert to ensure that the developed e-module met academic and pedagogical standards. This validation stage is an essential component of the Develop phase in the 4D model, as it determines the

product's feasibility before classroom implementation. Each expert evaluated the module using structured validation sheets covering specific indicators. The material expert focused on content accuracy and curriculum alignment, the media expert examined design and usability aspects, and the language expert assessed clarity and readability. The purpose of involving multiple validators was to ensure that the product was reviewed comprehensively from different professional perspectives. Through this systematic evaluation process, constructive feedback was obtained to refine the module before field testing. The summary of the validation results is presented in Table 3 below.

Table 3. E-Module Validation Results by Experts

No	Validator	Maximum Score	Score Obtained	Percentage (%)	Category
1	Materials Expert	80	78	97.5	Very Eligible
2	Media Expert	80	76	95.0	Very Eligible
3	Linguist	80	75	93.75	Very Eligible
	Average			95.42	Very Eligible

Based on Table 3, the material expert awarded 78 out of 80 points (97.5%), indicating that the content is highly aligned with learning objectives and scientifically accurate. The expert emphasized that the integration of project-based activities supports conceptual understanding and encourages problem-solving processes in accordance with elementary science competencies. The media expert provided a score of 76 out of 80 points (95%), highlighting strengths in visualization, interactivity, layout consistency, and navigation clarity. Meanwhile, the language expert gave 75 out of 80 points (93.75%), confirming that the module uses communicative, age-appropriate, and grammatically correct language. The overall validation average of 95.42% demonstrates that the e-module meets the feasibility criteria in terms of instructional design, media presentation, and linguistic clarity. These findings indicate that the developed product is suitable for limited implementation in classroom settings and supports the pedagogical integration of Project-Based Learning and deep learning principles.

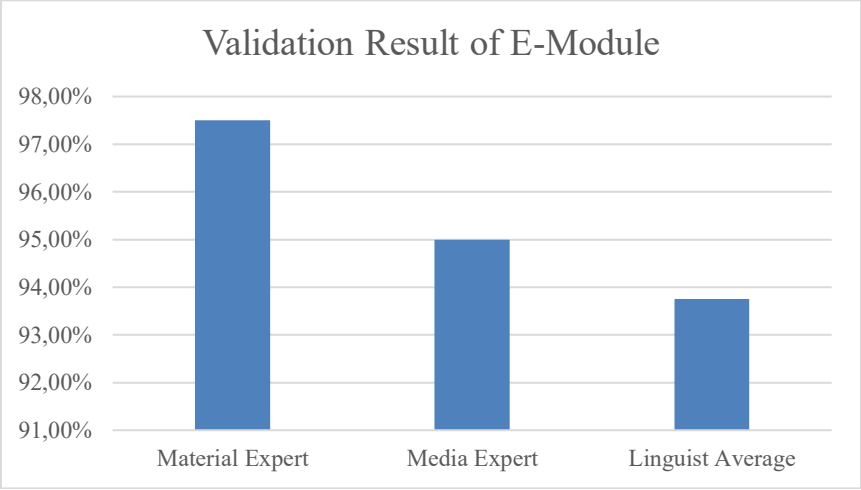

Figure 1. Diagram of Validation Results of E-Module

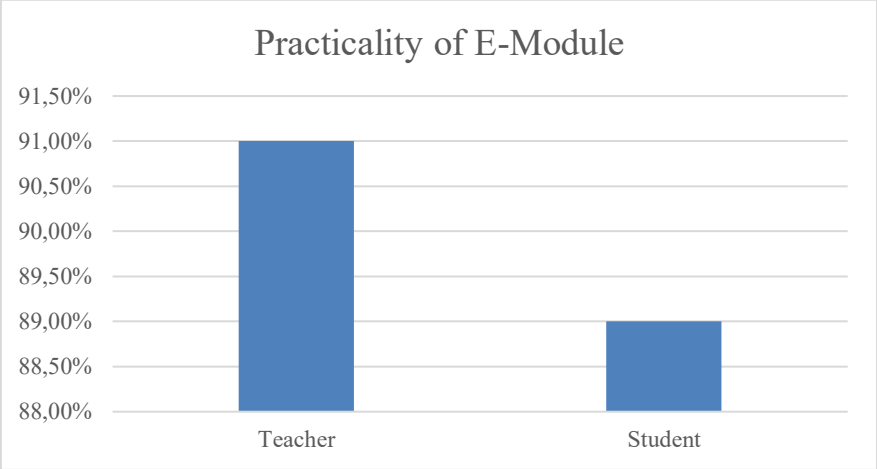

Figure 2. Practicality of E-Module

Practicality Test Results

The practicality test was conducted after the e-module had passed the expert validation stage. This stage aimed to determine whether the developed product could be implemented effectively in real classroom conditions. Practicality was assessed through questionnaires distributed to three teachers and fifteen fifth-grade students who used the e-module during limited field implementation. The teachers evaluated aspects such as clarity of instructions, ease of operation, suitability of project stages, and relevance to curriculum objectives. Meanwhile, students assessed attractiveness of design, ease of navigation, clarity of explanations, and overall learning experience. The use of two respondent groups allowed for triangulation of perceptions from both instructional and user perspectives. The results of the practicality test are presented in Table 4 below.

Table 4. Results of the E-Module Practicality Test

No	Respondents	Number of Respondents	Practicality Percentage (%)	Category
1	Teachers	3 people	91	Very Practical
2	Students	15 people	89	Very Practical
	Average		90	Very Practical

Based on Table 4, teachers gave a practicality score of 91%, while students provided a score of 89%, resulting in an overall average of 90%, categorized as "very practical." Teachers reported that the e-module was easy to integrate into classroom instruction and helped structure project-based learning stages systematically. The digital format simplified the delivery of materials and facilitated monitoring of student project activities. Students expressed that the module was visually attractive, interactive, and easy to follow independently. The structured guidance provided within each project phase supported their understanding of tasks and expectations. These findings indicate that the e-module is operationally feasible and supportive of science instruction implementation. Therefore, from a usability standpoint, the product demonstrates strong potential for classroom adoption.

Empirical Data on Problem-Solving Skills

Problem-solving skills were assessed based on five main indicators, namely identifying problems, formulating problems, designing solution strategies, implementing strategies, and evaluating as well as drawing conclusions. The assessment was conducted after students completed the project-based learning activities contained in the e-module. Overall, the results indicate that students demonstrated strong performance across most problem-solving stages. They were generally able to recognize scientific problems presented in contextual situations and translate them into structured problem statements. Students also showed the ability to design solution strategies and carry out project steps systematically in accordance with the given instructions. However, the evaluation and conclusion stage appeared to be slightly more challenging, as reflective reasoning and critical evaluation require deeper cognitive processing. These findings suggest that the structured project activities embedded in the e-module supported students in practicing systematic problem-solving processes. Nevertheless, since this study did not employ a comparative experimental design, the findings represent descriptive achievement outcomes following implementation rather than statistically verified evidence of improvement.

Empirical Data on Scientific Literacy

Scientific literacy was evaluated using dimensions that include conceptual understanding, application of concepts in daily life, scientific reasoning, interpretation of scientific information, and awareness of scientific issues. The assessment was administered after students engaged in learning activities within the developed e-module. The results indicate that students were generally able to understand and explain scientific concepts related to the human respiratory system in a clear and meaningful manner. They also demonstrated the ability to connect these concepts to real-life contexts, such as maintaining respiratory health and understanding environmental influences on breathing. In addition, students were capable of interpreting simple data representations and providing logical explanations based on scientific reasoning. The integration of contextual problems and project-based activities appears to have supported students in engaging more deeply with scientific content. However, as the research design focused on development and limited implementation, these findings describe students' performance profiles after using the e-module rather than establishing statistically tested effectiveness. Further research with a more rigorous experimental approach would be required to determine the extent of measurable learning gains.

Interpretation and Implications

Based on the validation and practicality data, it can be interpreted that the developed e-module demonstrates strong quality in terms of content accuracy, instructional design, media presentation, and language clarity. The high level of expert agreement indicates that the material aligns with curriculum standards and supports structured project-based learning stages. In addition, the positive responses from teachers and students suggest that the e-module is operationally feasible in

classroom settings. The integration of Project-Based Learning (PjBL) with a deep learning approach provides a structured yet reflective learning experience. Students are not only guided to complete projects but also encouraged to think critically and connect concepts with real-life situations. These findings imply that carefully designed digital learning media can support meaningful and participatory instruction. Therefore, the developed product can be considered pedagogically sound within the scope of limited field implementation.

The implications of these findings highlight the importance of integrating modern pedagogical approaches with accessible educational technology. Learning media development should not focus solely on content delivery but also on facilitating inquiry, collaboration, and reflection. The combination of PjBL and deep learning principles responds to the need for student-centered instruction in elementary science education. By embedding contextual projects and reflective questions, the e-module supports the development of higher-order thinking skills. This approach is relevant to current educational reforms that emphasize competency-based learning and independent student exploration. Furthermore, digital e-modules allow flexibility in implementation across various instructional settings, including blended learning environments. In this regard, the developed module has the potential to serve as an alternative instructional model that strengthens critical, independent, and creative reasoning aligned with the Pancasila student profile.

The findings related to students' problem-solving skills indicate that most learners were able to achieve performance levels above the Minimum Completion Criteria (KKM) after engaging with the e-module. The structured project activities, such as constructing a lung model and preparing reflective reports, provided opportunities for students to practice systematic problem-solving stages. Students were guided to identify problems related to respiratory symptoms, design appropriate solutions, implement their strategies, and evaluate outcomes. These processes reflect authentic scientific inquiry and promote practical reasoning skills. The results are consistent with the perspective of Gok and Erdogan (2017), who argue that project-based approaches enhance students' capacity to generate solutions grounded in data and observation. However, given the developmental nature of this study, these outcomes should be interpreted as descriptive post-implementation achievements rather than definitive causal evidence of effectiveness.

In terms of scientific literacy, students demonstrated strong ability to understand scientific concepts, interpret information, and communicate findings through project presentations and literacy-based tasks. Activities such as reading short scientific texts, creating educational posters, and discussing environmental factors affecting respiration helped students connect abstract concepts to real-world contexts. This contextual engagement supports deeper conceptual processing and meaningful knowledge construction. The findings align with Chen (2023), who emphasizes that deep learning encourages students to process information reflectively and link scientific ideas to everyday experiences. Furthermore, the assessment dimensions correspond to the scientific literacy framework proposed by Chiappetta et al. (1991), which highlights conceptual understanding, application, and communication of scientific knowledge. These consistencies suggest that the

e-module design is aligned with established theoretical perspectives on literacy development.

Overall, the interpretation of results indicates that the project-based e-module integrated with a deep learning approach supports science learning that extends beyond memorization. The structured integration of projects, reflection, and contextual analysis creates opportunities for students to engage in higher-order thinking processes. Although the research design does not permit strong causal claims, the descriptive data suggest promising outcomes in both problem-solving and scientific literacy domains. The alignment between instructional design, theoretical frameworks, and observed student performance strengthens the credibility of the development process. Consequently, this e-module represents an innovative instructional product that contributes to meaningful science education at the elementary level. Future studies employing more rigorous experimental designs would be valuable to further confirm its measurable impact on student learning outcomes.

Discussion

The findings of this study indicate that the Project-Based Learning (PjBL) e-module integrated with a deep learning approach meets the criteria of feasibility and practicality for elementary science learning. The high validation score (95.42%) from material, media, and language experts demonstrates that the product is systematically designed, conceptually accurate, and aligned with curriculum standards. The content suitability, clarity of language, and interactive design collectively support its potential as a structured learning medium. These findings confirm that the 4D development stages were implemented consistently, particularly in the Define and Design phases where curriculum alignment and student characteristics were analyzed carefully. Thus, from a product development perspective, the e-module fulfills the quality benchmarks required before classroom implementation.

The practicality test results further reinforce the usability of the developed e-module. Teacher responses (91%) and student responses (89%) indicate that the module is easy to operate, clearly structured, and engaging. Teachers reported that the module supports the systematic implementation of project stages, which often become a challenge in conventional teaching materials. Meanwhile, students perceived the module as attractive and helpful in guiding them through investigative activities. These findings suggest that the integration of digital features, reflective prompts, and structured project instructions enhances the learning experience. Importantly, practicality results reflect implementation feasibility in real classroom contexts rather than theoretical assumptions, strengthening the credibility of the development process.

Regarding students' problem-solving skills, the post-implementation data show that most students achieved scores above the Minimum Completion Criteria (KKM), with an overall average in the "very good" category. Students demonstrated competence in identifying problems, designing solution strategies, and

implementing project steps systematically. This outcome indicates that the project activities embedded in the e-module provide structured opportunities for analytical thinking and procedural reasoning. However, since this research did not apply a pre-test and post-test experimental comparison, the findings should be interpreted as descriptive achievement outcomes after implementation rather than statistically proven improvement. The results nevertheless suggest that the learning design is aligned with problem-solving indicators outlined in the instrument grid.

Similarly, the scientific literacy results reveal that students performed well across all measured dimensions, including conceptual understanding, application in daily life, scientific reasoning, and data interpretation. The integration of contextual respiratory system issues, such as air pollution and healthy breathing habits, appears to help students connect abstract concepts with real-life experiences. This contextualization reflects the principles of deep learning, where knowledge is not merely memorized but meaningfully constructed through reflection and application. The high literacy scores indicate that the e-module provides learning experiences that support comprehension and communication of scientific ideas. Nonetheless, as with problem-solving skills, these findings describe performance levels within a limited trial context and should not be generalized as definitive evidence of causal impact.

The combination of PjBL and deep learning principles within the e-module appears pedagogically coherent. Project-Based Learning structures the learning process through investigation and product creation, while deep learning principles encourage reflection, conceptual linkage, and meaningful understanding. This integration enables students to move beyond surface learning toward more analytical and reflective engagement with scientific material. The findings support theoretical perspectives suggesting that meaningful project engagement can strengthen higher-order thinking skills. In this study, the structured project tasks, reflective questions, and guided evaluation components appear to function synergistically in promoting deeper comprehension of the respiratory system topic. From a curriculum perspective, the developed e-module aligns with the orientation of student-centered and competency-based learning. The design supports independent exploration, collaborative discussion, and authentic assessment of learning processes and products. Such characteristics are consistent with contemporary educational reforms that emphasize critical thinking, creativity, and problem-solving competence. However, it is important to emphasize that this research primarily confirms product feasibility and descriptive learning outcomes within a limited sample. Broader implementation across different schools and student populations would be necessary to determine scalability and general applicability.

Despite the positive findings, several limitations should be acknowledged. The research design focused on Research and Development (R&D) using the 4D model and did not include a control group or statistical hypothesis testing. The field trial was conducted on a relatively small sample, which limits generalizability. Additionally, long-term retention of problem-solving and scientific literacy skills was not measured. These limitations suggest that further studies employing quasi-

experimental or experimental designs are required to strengthen claims regarding instructional effectiveness and to examine sustained learning impact over time.

Overall, the discussion indicates that the developed PjBL e-module integrated with a deep learning approach is a feasible and practical instructional product that demonstrates promising descriptive outcomes in problem-solving skills and scientific literacy. While the findings do not establish causal effectiveness, they provide empirical support that the learning design is pedagogically sound and aligned with competency-based science education. Future research integrating more rigorous effectiveness testing procedures will be essential to validate and expand upon these initial development findings.

4. Conclusion

This research produced a Project-Based Learning (PjBL)-based e-module integrated with a deep learning approach on the human respiratory system for elementary school students. The development results indicate that the e-module is highly feasible for use in science learning. This is evidenced by expert validation, which yielded an average feasibility percentage of 95.42%, placing the product in the highly feasible category. In addition, practicality tests conducted by teachers and students showed very positive results, with average scores of 91% from teachers and 89% from students, indicating that the e-module is highly practical and easy to use in the learning process. Beyond its feasibility and practicality, the e-module also demonstrated effectiveness in improving students' problem-solving skills and scientific literacy. The project activities embedded within the module encourage students to think reflectively, relate scientific concepts to real-life situations, and actively participate in meaningful learning experiences. Through the integration of a deep learning approach, students are guided to achieve deeper conceptual understanding and to develop higher-order thinking skills. Overall, this e-module has strong potential to be implemented as an innovative science learning medium. It supports the strengthening of the Pancasila student profile while serving as an example of contextual, student-centered, and curriculum-aligned digital media development in elementary education.

Acknowledgement

The author expresses her deepest appreciation to all parties who contributed to the implementation and completion of this research. Special thanks are extended to the supervising lecturer for their guidance, direction, and constructive input throughout the development of this article. Thanks are also extended to the material experts, media experts, and language experts who validated and evaluated the developed e-module, resulting in a feasible and high-quality product. The author also thanks the principal, teachers, and students at the elementary school where this research was conducted for their cooperation and active participation in the practicality testing and implementation of project-based learning activities. The support of colleagues and other parties, not mentioned individually, was invaluable in the preparation, data collection, and completion of this article. Hopefully, the results of this research

can make a positive contribution to the development of science learning media at the elementary school level..

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How to cite this article:

Susilowati, E., Pratiwi, D., Rossa, F. O., & Aththibby, A. R. (2026). Development of PjBL E-Modules with a Deep Learning Approach for Problem Solving and Scientific Literacy. *Journal of Educational Sciences*, *10(4)*, 13-27.