Journal of Applied Science Education and Innovation
Vol. 1, No. 1, April 2026, pp. 1~11
DOI: https://doi.org/xxxxxxxxxx

p-ISSN: xxxx-xxxx
e-ISSN: xxxx-xxxx

DEVELOPMENT OF PJBL E-MODULES WITH A DEEP LEARNING APPROACH FOR PROBLEM SOLVING AND SCIENCE LITERACY

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Article History
Received: 11/02/2026
Revised: 16/02/2026
Accepted: 18/02/2026
Published: 01/04/2026
Keywords:
e-modules; project-based learning; deep learning; respiratory system; science literacy; problem solving

Abstract. The low level of science literacy and problem-solving skills among elementary school students indicates the need for innovative learning media that is meaningful, contextual, and tailored 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 engagement, reflective thinking, and deep understanding. The development model used is 4D (Define, Design, Develop, Disseminate). The Define stage was carried out by analyzing the curriculum and student needs. The Design stage produced an e-module design with a project structure that integrated critical thinking activities. The Develop stage involved expert validation of the material (score of 78/80), media (76/80), and language (75/80) with a rating of "very feasible." The Disseminate stage was carried out through a practical test that showed very positive results, with an average score of 91% from teachers and 89% from students. The e-module was considered interesting, communicative, easy to use, and encouraged independent learning and improved science literacy. The results of this study indicate that the developed e-module is feasible and practical for use in science learning in elementary schools.

How to Cite: Susilowati, Endang; Maria, Enni. (2026). Development of PjBL E-Modules with A Deep Learning Approach for Problem Solving and Science Literacy. Journal of Applied Science Education and Innovation, 1(1), 1-11. https://doi.org/10.29xxx/jrst.vxxx.xxxx

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Introduction

Science education in elementary schools plays an important role in shaping scientific thinking, curiosity, and students' ability to critically understand natural phenomena. Unfortunately, the dominant practice of rote learning makes it difficult for students to relate scientific concepts to everyday life. This results in weak conceptual mastery and low higher-order thinking skills among students (Rusilowati, et al., 2019). Low scores on international assessments such as the Programme for International Student Assessment

(PISA) reinforce these findings. PISA 2018 shows that Indonesian students' science literacy performance is still below the international average, largely due to a lack of meaningful learning and student involvement in solving real-world problems (OECD, 2019).

One approach that can address these challenges is Project-Based Learning (PjBL). PjBL is a learning model that emphasizes the process of investigation and problem solving through project activities. This approach has been proven effective in improving students' conceptual understanding, critical thinking skills, and problem-solving skills (Lestari, et al., 2022). Lestari et al. (2022) emphasize that project-based science learning integrated with science literacy reinforcement not only improves cognitive learning outcomes but also encourages students to relate scientific knowledge to everyday contexts. This creates meaningful and applicable learning in solving scientific problems reflectively and analytically.

Despite its many advantages, the implementation of PjBL in elementary schools still faces various obstacles, one of which is the limited availability of learning media specifically designed to support PjBL. Teachers need teaching materials that can facilitate the project stages in a systematic, structured, and easy-to-use manner, both in face-to-face and digital learning. E-modules are a potential solution to address these needs. This medium allows for interactive, visual delivery of material accompanied by project-based activities and evaluations. Research shows that the use of e-modules in learning can increase student motivation, participation, and learning outcomes, especially in the context of distance learning (Holisoh et al., 2023).

In order for e-modules to promote in-depth conceptual understanding, deep learning approaches need to be integrated into their design. Deep learning emphasizes reflective thinking, conceptual understanding, and connections between old and new knowledge, so that students do not simply memorize but understand and apply knowledge (Hmelo-Silver & Duncan, 2007). The integration of Project-Based Learning and deep learning is believed to result in comprehensive learning. This combination allows students to experience a more active, collaborative, and meaningful learning process. In addition, this approach is considered capable of developing 21st-century skills such as communication, collaboration, creativity, and critical thinking (Nais et al., 2023). The human respiratory system was chosen as the focus of development because it is essential material that is often considered abstract by elementary school students. With a project-based approach, the concept of the respiratory system can be explained through simple simulations or experiments that are relevant to everyday life, making it easier for students to understand the concept concretely.

Based on this background, this study aims to develop a Project-Based Learning-based e-module that integrates a deep learning approach to human respiratory system material. This e-module is expected to improve students' problem-solving and science literacy skills and become a valid, practical, and contextual learning medium in elementary schools. In the context of the Merdeka Curriculum, learning is directed at developing higher-order thinking skills and independent learning competencies in students. Teachers

are required to design student-centered learning and provide ample room for exploration through project activities. The development of PjBL-based e-modules integrated with deep learning is in line with this policy direction because it is able to provide challenging, collaborative, and in-depth learning experiences (Suryana et al., 2023). In addition to supporting the implementation of an adaptive curriculum, the use of e-modules is also relevant to current developments in educational technology. The results of the study show that digital-based learning designed according to modern pedagogical principles can increase the effectiveness and efficiency of the learning process. E-modules that are compiled with consideration of project-based learning stages and a deep learning approach will meet the need for learning media that is not only informative but also transformative (Putra & Abdurrahman, 2022).

Methode

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 to be applied in the classroom learning process. The Define stage aims to analyze needs, including curriculum analysis, student characteristics, and initial identification of problems related to low science literacy and problem-solving skills among students. The Design stage involves designing e-modules using a Project-Based Learning (PjBL) approach and integrating deep learning principles, as well as preparing research instruments such as validation sheets, practicality questionnaires, and student ability tests.

The Develop stage was carried out through the validation of subject matter, media, and language experts. Each validator assessed the aspects of content suitability, readability, media display, and suitability with the characteristics of elementary school students. The Disseminate stage was carried out by testing the practicality for teachers and students to obtain empirical data on the feasibility of implementing e-modules in the learning process. The instruments used in this study included validation sheets, practicality questionnaires, and tests to measure students' problem-solving and science literacy skills. These instruments were developed based on relevant indicators and validated before use.

Table 1 is an outline of the problem-solving ability instrument used in the study:

Table 1. Problem Solving Ability Instrument

Number	Indicator	Assesment Descriptor	Question Number
1	Identifying Problems	Students are able to recognize and explain problems from the given context.	1
2	Formulating Problems	Students are able to formulate problems using clear and logical sentences.	2
3	Designing Solution Strategies	Students are able to determine and design steps to solve problems.	3

Number	Indicator	Assesment Descriptor	Question Number
4	Implementing Strategies	Students are able to implement solution steps systematically and appropriately.	4
5	Evaluating and Drawing Conclusions	Students are able to evaluate the results and draw conclusions about the solutions implemented	5

In addition to problem-solving skills (Table 2), science literacy was also measured using instruments developed from OECD indicators and Chiappetta et al. (1991).

Table 2. Problem Solving Ability Instrument

Number	Dimension of Science Literacy	Assessment Indicators	Question Numberl
1	Understanding 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 situations in their surroundings	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 the graphs/tables presented	4
5	Awareness of scientific issues	Students show concern for the importance of maintaining respiratory health	5

Result and Discussion

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 linguists, and its practicality was tested by teachers and students. The following are the results of each development stage.

Expert Validation Results

The validation process (Tabel 3) was conducted by three experts: material, media, and language experts. The summary of the assessment results is as follows:

1. The Material Expert gave a total score of 78 out of 80 points, or 97.5%, categorized as "very suitable." The assessment covered the content's suitability to learning outcomes, the depth of the material, and the integration of project-based activities that encourage problem-solving and conceptual understanding.
2. The Media Expert gave a score of 76 out of 80 points, or 95%, with assessments covering aspects of visualization, interactivity, navigation between pages, and media integration that supports students' reflective thinking.
3. The Language Expert gave a score of 75 out of 80 points, or 93.75%, indicating that the language used is appropriate to the students' ability level, communicative, and free from spelling and sentence structure errors.

The overall average validation (Tabel 4) score was 95.4%, indicating that the e-module is considered very suitable for use in project-based science learning in elementary schools. This finding aligns with the research of Lestari et al. (2022), which states that learning media designed by integrating literacy and contextual activities can increase the feasibility of the material and the effectiveness of science learning.

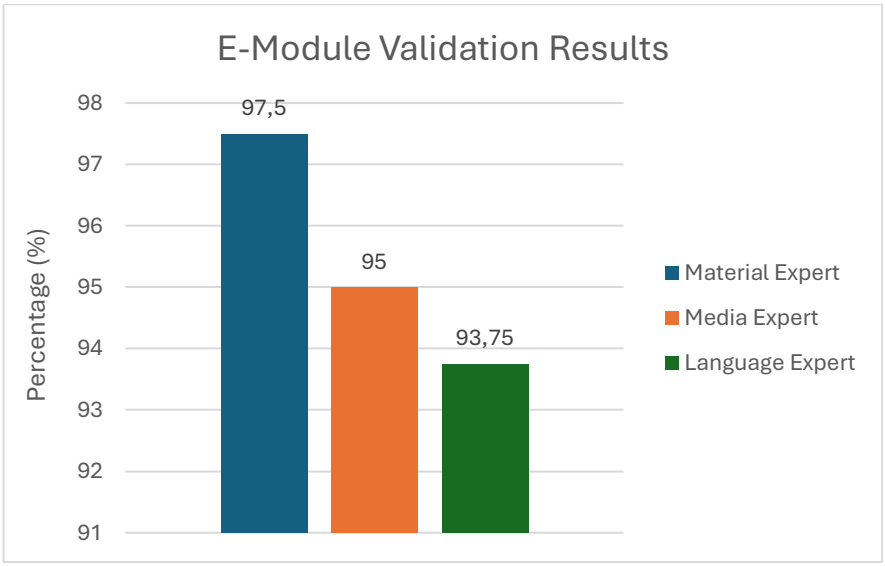
To clarify the description of the research results, the following is a summary of data in the form of tables and visual diagrams that illustrate the level of feasibility and practicality of the e-module developed (Picture 1 and Picture 2).

Table 3. E-Module Validation Results by Experts

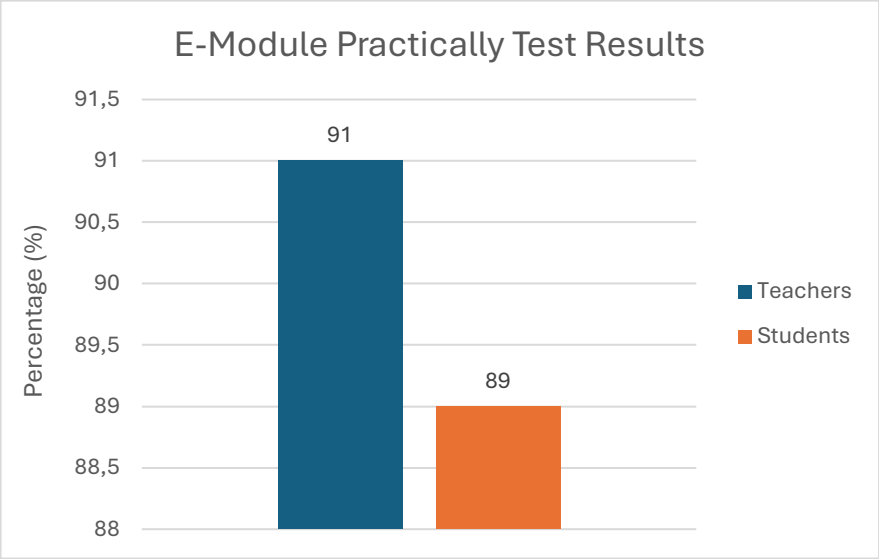
Number	Validator	Maximum Score	Score	Percentage (%)	Category
1	Material Expert	80	78	97.5	Very Appropriate
2	Media Expert	80	76	95.0	Very Appropriate
3	Language Expert	80	75	93.75	Very Appropriate
	Average			**95.42**	**Very Appropriate**

Table 4. E-Module Practicality Test Results

Number	Respondents	Number of Respondents	Percentage Practicallt (%)	Category
1	Teachers	3	91	Very Practical
2	Students	15	89	Very Practical
	Average		**90**	**Very Practical**



Picture 1. E-Module Validation Results by Experts



Picture 2. E-Module Practically Test Results

Practically Test Results

A practicality test was conducted on three teachers and 15 fifth-grade students. Teachers were asked to rate aspects of ease of use, clarity of instructions, and relevance of content and assignments. Meanwhile, students assessed aspects of the module's appearance, ease of navigation, and attractiveness.

1. Teachers' results showed an average practicality score of 91%, categorized as "very practical." Teachers stated that the e-module was easy to operate, the instructions were clear, and it was very helpful in facilitating project-based learning in the classroom.
2. Students' results showed an average score of 89%, also categorized as "very practical." Students found the e-module engaging, easy to understand, and encouraged them to think and actively participate in projects.

These results indicate that the e-module is not only feasible but also easy to implement in daily learning activities. This aligns with research by Fitri & Asrizal (2023), which stated that interactive PjBL-based e-modules provide meaningful learning experiences and increase student engagement and understanding in the context of science material.

The Relation Between Problem Solving Ability and Scientific Literacy

Students' problem-solving skills and scientific literacy were developed through project activities within the e-module, such as creating a simple lung model, observing respiration, and conducting scientific reflection. Based on limited testing results, students demonstrated the ability to identify problems, design solutions, and draw scientific conclusions from the activities undertaken.

Furthermore, students were able to relate respiratory system concepts to healthy lifestyle habits, understand respiratory charts, and convey scientific ideas orally and in writing. These activities foster scientific literacy, encompassing conceptual understanding, real-life applications, and awareness of everyday scientific issues. These findings support the

findings of Rusilowati et al. (2019) that integrating PjBL into science significantly develops scientific thinking skills.

Interpretation and Implications

Based on validation data and practicality tests, it can be concluded that the developed e-module is of excellent quality in terms of content, media, and language suitability, and is practical for both teachers and students. The development of a project-based e-module integrated with deep learning has proven effective in fostering more contextual, participatory, and reflective learning. The implications of these results suggest that the development of learning media needs to consider the integration of modern pedagogical approaches, student needs, and the use of easily accessible educational technology. Going forward, this type of e-module can become an alternative science learning method that can strengthen the profile of Pancasila students, particularly in the areas of critical, independent, and creative reasoning.

The research results show that the Project-Based Learning (PjBL)-based e-module, integrated with a deep learning approach, significantly contributed to improving elementary school students' problem-solving skills and scientific literacy. Based on trial data, 26 out of 30 students (86.7%) achieved scores above the Minimum Completion Criteria (KKM) in the problem-solving aspect. This indicates that the e-module is categorized as "very effective" in improving students' problem-solving skills.

Problem-solving skills were assessed through project assignments such as creating a lung model and compiling a reflective report. These tasks trained students to identify problems (symptoms of respiratory disorders), design solutions (creating a simple breathing apparatus), and evaluate the results. Students were also asked to present their solutions in class. This activity integrated all stages of scientific thinking and developed practical and realistic problem-solving skills. These findings align with the theory of Gok & Erdogan (2017), which states that a project-based approach can improve students' ability to develop solutions based on data and field observations.

Meanwhile, in the scientific literacy indicator, 28 students (93.3%) demonstrated high achievement in understanding scientific concepts, interpreting data, and communicating results. Reading short scientific texts, creating educational posters, and delivering project presentations were part of the scientific literacy assessment instruments in this e-module. These activities helped students connect the respiratory system material to real-life situations, such as the causes of shortness of breath, the importance of clean air, and the impact of smoking.

The average student scientific literacy score reached 87.5%, placing them in the "very good" category. This aligns with Chen's (2023) findings, which state that the deep learning approach encourages students to process information more meaningfully through reflection and exploration of phenomena relevant to everyday life. Students not only understand concepts but are also able to explain, relate, and communicate scientifically, as mandated by the scientific literacy indicators according to Chiappetta et al. (1991).

Thus, it can be concluded that the use of this project-based e-module significantly supports science learning, which focuses not only on cognitive aspects but also on the development of higher-order thinking skills. Research data directly reinforces that this approach is effective in developing students who are scientifically literate and skilled at solving problems, which are key characteristics of 21st-century learners.

The research results show that the Project-Based Learning (PjBL) e-module, integrated with a deep learning approach, proved feasible, practical, and effective for use in elementary school science instruction, particularly on the human respiratory system. Validation by material, media, and language experts showed a very high percentage (an average of 95.42%), indicating that the content, presentation, and language of the e-module met the project-based learning needs of elementary school students.

The practicality of the e-module, as tested through teacher and student responses, also showed very positive results. Teachers considered the e-module very helpful in facilitating active and meaningful learning, while students found it easy to use and engaging. This aligns with the findings of Surjono (2022) who stated that e-modules developed with the principles of interactivity and real-world contexts can enhance students' learning independence.

The effectiveness of the e-module is reflected in the improvement in students' problem-solving skills and scientific literacy. Project activities such as creating lung models and observing respiratory symptoms encourage students to not only memorize concepts but also apply them in real-life situations. The deep learning approach used in the e-module encourages in-depth, reflective, and meaningful thinking, as Chen (2023) emphasized, explaining that science learning based on reflection and contextual exploration strengthens students' scientific competencies.

The application of Project-Based Learning in the e-module has also been shown to bridge the gap between theory and practice. Students not only understand the respiratory system conceptually but also recognize the importance of maintaining respiratory health in everyday life. This finding aligns with research by Yusmar & Riska (2023), who found that elementary school students involved in science projects demonstrated increased scientific literacy and awareness of health issues.

Overall, the integration of PjBL and deep learning in the form of an e-module provides a more meaningful, contextual learning experience, oriented toward developing 21st-century competencies. This e-module serves not only as a learning medium but also as an authentic assessment tool that assesses students' learning processes and products. In other words, this innovation supports the direction of the Independent Curriculum, which emphasizes project-based, differentiated, and real-life learning.

Conclusion

This research resulted in a Project-Based Learning (PjBL) e-module integrated with a deep learning approach on the human respiratory system for elementary school students. Based on expert validation, the e-module was deemed highly feasible, with an average feasibility score of 95.42%. Furthermore, practicality tests conducted by teachers and

students indicated that the e-module fell into the highly practical category, with average scores of 91% and 89%, respectively.

This e-module also proved effective in improving students' problem-solving skills and scientific literacy. The projects presented in the e-module encouraged students to think reflectively, connect scientific concepts to everyday life, and actively engage in meaningful learning. The deep learning approach applied fostered deeper conceptual understanding and higher-order thinking skills. Therefore, this e-module has great potential for implementation as a science learning medium that supports the strengthening of Pancasila student profiles and serves as an example of the development of innovative, contextual, and student-centered curriculum-based digital media.

Recommendations

Based on the findings and conclusions of this study, several recommendations are addressed to various parties to support the utilization and further development of Project-Based Learning (PjBL)-based e-modules integrated with a deep learning approach, Students are advised to use these e-modules actively, not only by reading the material but also by directly engaging in the designed project activities. These activities are expected to encourage students to think critically, solve problems scientifically, and relate science concepts to the realities of everyday life; Teachers need to utilize these e-modules as an alternative learning medium that is contextual, engaging, and student-centered. An understanding of the principles of PjBL and deep learning is necessary so that teachers can guide students in implementing projects, provide reflective feedback, and design authentic project-based assessments. Therefore, training or mentoring for teachers is highly recommended; Schools are expected to provide support in the form of adequate ICT facilities for the implementation of these e-modules and conduct programs to improve teacher competency in the use of digital media. This e-module can be used as part of a science learning innovation that aligns with the principles of the Independent Curriculum, particularly differentiated and project-based learning; For Researchers: Further research is recommended to test the effectiveness of the e-module more broadly using both quantitative and qualitative approaches, and involving a more diverse sample. Researchers can also develop similar e-modules for other educational materials and levels, with a focus on enhancing 21st-century competencies such as creativity, collaboration, scientific literacy, and problem-solving; For Media Developers: The developed e-modules can still be refined in terms of content, multimedia integration, and interactivity. Further development should be based on student needs and developments in educational technology, so that the resulting product remains relevant and engaging for the digital learner generation.

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