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Integrated Interactive E-Module for Project-Based Learning to Enhance Independence and Conceptual Understanding of Alternative Energy

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Abstract

This study aims to develop an interactive e-module integrated with the Project-Based Learning (PjBL) model to enhance junior high school students' independence and understanding of alternative energy concepts. Using the ADDIE-based Research and Development (R&D) method, the process included analysis, design, development, implementation, and evaluation stages. Expert validation, along with readability and practicality tests involving students, was conducted using various instruments, including questionnaires and pretest-posttest evaluations. The e-module achieved high validity, with Aiken's V scores of 0.94 for both media and content. It also gained high readability (84.3%) and practicality (89%) scores. The Wilcoxon test ($p < 0.001$) and a normalized gain of 0.75 indicated a significant improvement in students' conceptual understanding. Additionally, the rate of learning independence increased by 85%. The Mann-Whitney test confirmed significant differences between experimental and control groups, proving the module's effectiveness in digital and contextual science learning. Overall, the e-module is effective for project-based science education. The study recommends applying similar approaches in other subjects and integrating advanced technology to support personalized and effective learning in the 21st century.

How to Cite

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INTRODUCTION

Education is the primary foundation for shaping an independent, creative, and innovative generation. In the era of the Industrial Revolution 4.0, the education system must transform in line with technological advances to create an effective learning process that meets the needs of the times (Nursyifa, A., 2019). In Indonesia, the use of digital technology in education is experiencing rapid development, particularly through online learning and web-based media, which make it easier for teachers to deliver material and encourage students to learn independently (Rijal, 2020).

Despite its great potential, the implementation of technology in learning still faces various challenges. One problem that often arises is the distraction of students' attention due to the use of digital devices, such as social media notifications, which can divert the focus from learning (Hakim & Yulia, 2024). In addition, learning methods that are still dominated by conventional lectures lead to low student active participation and have not encouraged optimal learning independence (Soesilo et al., 2021; Sudjana, 2021).

Therefore, teachers need to develop digital teaching materials that are engaging, interactive, and aligned with the characteristics of 21st-century learners. One potential solution is the development of interactive e-modules integrated with a Learning Management System (LMS) platform. LMS enables the systematic management of learning, from material preparation and evaluation to monitoring student activities (Setiaji et al., 2022; Mardiana & Faqih, 2019). Through the LMS, students can access materials at their own pace and according to their preferred learning style.

Web-based e-modules offer a more personalized learning experience by integrating multimedia elements, including videos, animations, and interactive practice questions. This module facilitates an in-depth understanding of concepts while promoting independent learning (Sukmawati et al., 2023; Sofa & Zahra, 2022). According to Mayer (2009), well-designed multimedia-based learning can optimize students' cognitive processes by integrating text and visuals.

In the context of junior high school science learning, the learning outcomes in Phase D, as stated in Permendikbudristek No. 5 of 2023, emphasize the importance of understanding environmental issues, especially the use of renewable energy. Alternative energy materials are crucial to be introduced early on, given the low awareness of some students of the importance of energy efficiency (Jamil et al., 2021). Therefore, learning strategies that can connect scientific concepts to real-life applications are needed.

However, current studies on digital science learning materials often focus on general interactivity without systematically integrating project-based approaches that promote active, contextual engagement. Moreover, most available e-modules are not yet integrated with Learning Management Systems (LMS), which limits their scalability and effectiveness in managing student-centered learning.

There is a gap in the development of LMS-based interactive e-modules that specifically adopt the Project-Based Learning (PjBL) model in the context of alternative energy topics at the junior high school level. This topic is critical because awareness of renewable energy remains low among students, and conventional teaching methods are insufficient to foster meaningful understanding. The urgency of this research lies in the need to provide innovative digital learning tools that not only utilize technology but also incorporate pedagogical strategies proven to enhance 21st century skills.

The Project-Based Learning (PBL) model is the right approach to overcoming these problems. PjBL emphasizes active student involvement through project activities that develop critical thinking, collaboration, and problem-solving skills (Thomas, 2000; Nugraha et al., 2023). This model has been proven effective in enhancing concept understanding, promoting learning independence, and increasing student motivation in science learning (Rahayuningsih et al., 2022; Rahmawati & Airlanda, 2023).

This study offers novelty by combining LMS technology with an interactive PjBL-oriented e-module tailored to alternative energy materials in science learning. Unlike previous studies that either focus on PjBL or LMS separately, this research integrates both in a coherent digital learning product to improve student independence and conceptual understanding.

This research aims to develop an LMS-based interactive e-module integrated with the Project-Based Learning (PBL) model on alternative energy materials for junior high school students. This innovation is expected to provide a solution for improving conceptual understanding and student learning independence through contextual, interactive, and meaningful learning. Additionally, this product offers novelty in its integration of digital platforms and project-based pedagogical approaches, aligning with the de-

mands of 21st century learning.

METHOD

This study employs a Research and Development (R&D) approach, utilizing the ADDIE development model, which comprises five systematic stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The ADDIE model was chosen due to its flexible, iterative, and needs-based characteristics in the field, allowing for continuous improvement at each stage of development (Molenda, 2003). To provide a comprehensive overview of the research procedure, the summary of activities, instruments, and analytic techniques used at each stage of ADDIE is presented in Table 1.

Table 1. Research Design

Addie Stage	Activities	Research Subject	Instrument / Data	Analysis Tecnique
Analysis	Interview with teachers; identification of learning needs and technology gaps	Student and Teacher	Interview guide	Qualitative analysis
Design	Designing Content, media, learning flow, and asessment tools	Teacher, Media Expert, Material Expert	Interactive e-module integrated PjBL, validation sheets	Expert revier
Development	Building e-modul (canva & laravel) expert validation, readability test	Media Expert, Material Expert, Student X grade	Validation questionaired. Readability instruments	Descriptive analysis
Implementation	Classroom application. Pretest-posttest	Student IX grade (Experimental and Control Class)	Test instruments, independence quetionnaires	N-gain, wilcoxon, Mann-Whitney U
Evaluation	Final revisionbased on student and teacher feedback	Student and Teacher	Practicality quetionnaires, evaluation notes	Qualitative and quantitative evaluation

Data analysis

Both descriptive and inferential statistical techniques were applied in this study. Prior to measuring the effectiveness of the e-module on learning outcomes, expert validation data were analyzed to determine the content validity of the developed product. The validation results from material and media experts were quantified using the Aiken's V coefficient. The degree of agreement among experts was calculated using Aiken's V formula as follows.

$$V = \Sigma s/\big(n(c-1)\big)$$

s = r – 1 : The deviation of each rating from the lowest category

r : Rating score given by an expert

1 : The lowest score in the rating scale

n : Number of experts

c : Number of rating scale categories

To interpret the magnitude of the V coefficient, the following category criteria were used.

Table 2. Aiken's V Validation Categories

Aiken's V value	Interpretation
V < 0.40	Low validity
0.40 < V < 0.80	Moderate validity
V > 0.80	High validity

After confirming that the e-module achieved acceptable validity and readability levels, the effectiveness of the product was examined through improvements in students' conceptual understanding. This was measured using pretest and posttest results. Students' improvement scores were analyzed using the normalized gain (N-gain) formula.

$$\text{<N-gain>} = \frac{Spost - Spre}{Smax - Spre}$$

Explanation:

N-gain	:	Conceptual understanding values
S_{pre}	:	Pre-test Score
S_{post}	:	Post-test Score
S_{max}	:	Maximum Score

The level of conceptual understanding in Table 3.

Table 3. Level of Conceptual Understanding

Score	Criteria
$0.7 \leq g \leq 1$	High
0.3 g 0.7	Medium
0< g 0.3	Low

Inferential analysis was carried out to determine the statistical significance of learning improvements and group differences. The Wilcoxon Signed-Rank Test was employed to analyze within-group changes between pretest and posttest scores, while the Mann–Whitney U Test was used to compare learning outcomes between groups. Both tests were selected because the data did not meet normality assumptions, making non-parametric procedures more appropriate for this study. Questionnaire data related to validity, readability, practicality, and learning independence were analyzed descriptively. Mean scores from expert and student evaluations were converted into qualitative categories to assess the feasibility and usability of the e-module. This analysis provided an overview of user responses and identified aspects requiring refinement. Data interpretation was conducted through the triangulation of test scores, questionnaire results, and expert feedback to ensure comprehensive and credible conclusions. The findings guided product revisions and supported the feasibility of broader implementation of the e-module for contextual and technology-based science learning. The flow of ADDIE research is illustrated in Figure 1.

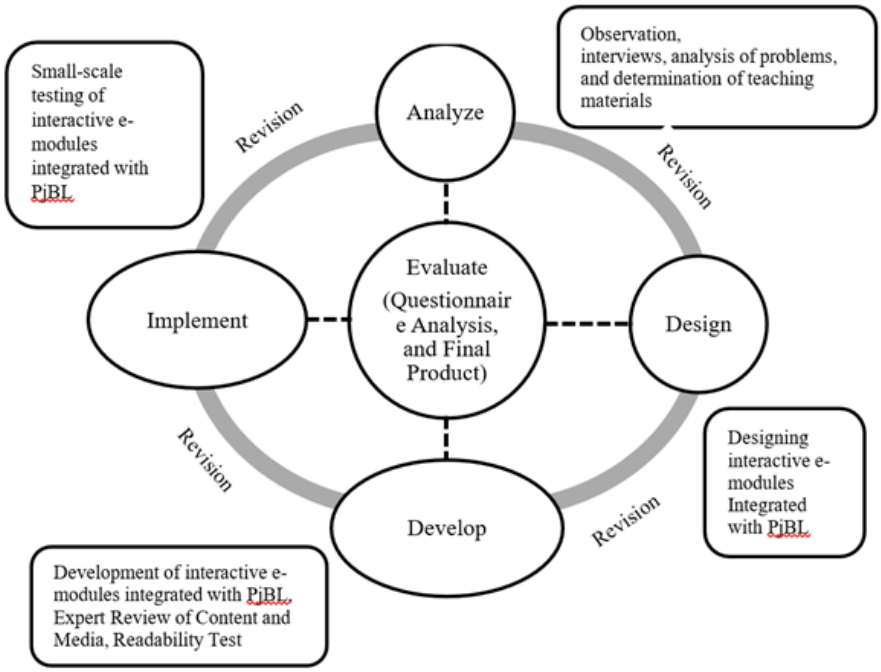


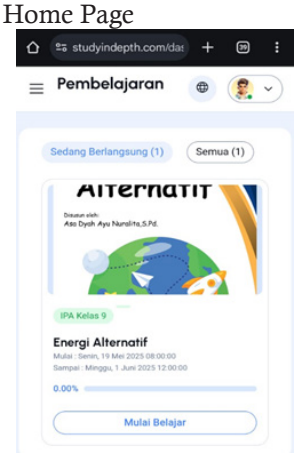
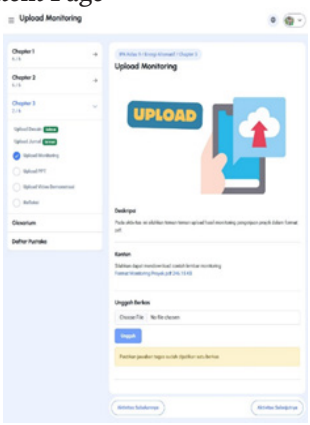
Figure 1. Research Flow

RESULT AND DISCUSSION

After developing the LMS-based e-module using the Laravel framework which enables a structured and modular system through the MVC architecture, he next step is to describe the interface features that support its pedagogical functions. To address the reviewer's suggestion for clearer descriptions, the main LMS and e-module are presented in Table 3, along with explanations of their roles in facilitating PjBL activities, student autonomy, and conceptual understanding.

These interface displays collectively demonstrate how the LMS-based interactive e-module operationalizes the Project-Based Learning model through structured project instructions, multimedia explanations, self-assessment tools, and reflective components. Each feature contributes to fostering student autonomy, enhancing conceptual understanding, and supporting meaningful engagement in alternative energy learning.

Table 3. Interface Displays of the LMS and Interactive E-Module

Pictures	Description
LMS Dashboard Page 	The LMS dashboard provides a visual summary of students' activity time and access patterns, along with navigation menus for modules, assignments, and assessments. This interface supports learning independence by allowing students to monitor their progress and quickly access the learning components required for PjBL activities.
E-Module Home Page 	The e-module home page displays the introductory section of the alternative energy topic, including competency indicators, learning outcomes, and project instructions. This page guides students to understand the learning objectives and the sequence of tasks within the PjBL framework.
Content Page 	The content page delivers structured explanations through text, images, videos, and interactive elements. Each learning segment is aligned with the PjBL workflow, gradually preparing students for a final project that involves designing or applying an alternative energy solution. The materials provide both conceptual foundations and practical guidance, enabling students to connect scientific theory with hands-on project implementation.
PJBL Content Page 	The Upload Monitoring page facilitates the PjBL process by allowing students to submit documentation of each phase of their alternative energy project. The interface provides task descriptions, file format requirements, and templates for monitoring progress. This feature enables teachers to track student development, give feedback, and ensure structured project completion within the LMS environment.

Prior studies reported that digital modules with strong interactive and visual components significantly enhance both conceptual understanding and student independence (Adilla et al., 2024; Tarigan et al., 2021). In science learning, multimedia-supported modules have also been shown to improve students' retention and critical thinking by providing multimodal representations of scientific concepts (Nsabayezu et al, 2025).

Table 4. Aiken V Results of E-Module Media Validity

No	Aspect	Results
1	Graphics	0.96
2	Interactive	0.91
3	Effectiveness	0.93
4	Quality	0.95
Average Percentage		0.94
Criteria		Very Valid

Validation of the e-module was conducted by five experts, consisting of two lecturers and three science teachers. Media validity was assessed based on four aspects: graphics, interactivity, effectiveness, and quality. The analysis produced an Aiken's V coefficient of 0.94, which falls into the very valid category. This result indicates that the module's visual design, interactive features, and functionality meet expert criteria for high-quality learning media. These findings correspond to previous research showing that digital modules with high interactivity receive strong feasibility ratings and effectively support student engagement (Sintawati & Margunayasa, 2021; Kania et al., 2024).

Table 5. Recapitulation of the Validity of E-Module Materials

No	Aspect	Results
1	Content	0.95
2	Language	0.92
3	Presentation	0.95
Average Percentage		0.94
Criteria		Very Valid

Material validity was assessed using three aspects: content accuracy, language clarity, and presentation structure. The material validation results yielded an Aiken's V value of 0.94, also classified as very valid, indicating that the learning material is accurate, understandable, and systematically organized. Similar studies have reported that e-modules developed through structured frameworks such as ADDIE and integrated with PjBL consistently achieve high validity scores due to their alignment with competency-based and student-centered learning approaches (Triwoelandari et al., 2023; Sagala & Eri, 2021). Therefore, the LMS-based interactive e-module developed in this study demonstrates strong feasibility for implementation in science learning. Tables 4 and 5 summarize the detailed results of the media and material validity assessments, both of which indicate consistently high Aiken's V values across all evaluated aspects.

The developed e-module underwent several stages of revision and was tested for readability among class X students of SMK Theresiana. This readability test aims to determine the extent to which the content and presentation of the e-module can be understood independently by students. The test was conducted on a small scale, involving 10 students as the sample. The test results showed that the e-module obtained a readability percentage of 84.3%, which was categorized as very good (Rusmansyah et al., 2023). This indicates that the e-module design aligns with the cognitive characteristics and learning styles of students, as suggested by Erika (2019), who emphasize that effective teaching materials should be communicative, engaging, and easily understood by students. This finding is consistent with Prihatiningtyas & Sholihah's research (2020), which reported an average readability value of 82.9% in PjBL-based e-modules, indicating that the ADDIE design in PjBL e-modules produces teaching materials that are easy to understand.

After undergoing the validation process and readability test, the e-module was implemented in the learning process as a treatment for the experimental class. At this stage, the experimental class followed science learning with the topic of alternative energy using interactive e-modules. In contrast, the control class received the same material through conventional methods (lectures). This difference aims to test the effectiveness of using e-modules on concept understanding and student learning independence. According to Ernawati and Susanti (2021), e-module-based learning enables students to learn flexibly and actively, making it a suitable approach for 21st-century learning.

The interactive e-module consists of three main chapters: (1) various kinds of alternative energy, (2) solar energy and its applications, and (3) solar energy utilization projects. The preparation of the material follows the Project-Based

Learning (PBL) framework, which aims to foster critical thinking skills, collaboration, and increase student learning independence. The learning process lasted for 18 days, during which experimental class students accessed the e-module through the Learning Management System (LMS) platform independently or in groups. The integration of PjBL in the e-module aims not only to improve conceptual understanding but also to provide a contextual experience in solving real-world problems, as suggested by Zhang & Ma (2023) and Gomes et al. (2025) within the framework of project-based learning. This finding aligns with the research of Wahyuni et al. (2025), which indicates that expert validation demonstrates that the PjBL module is highly feasible for use.

The implementation stage of this study generates data related to concept understanding, learning independence, and the effectiveness of using interactive e-modules based on the Learning Management System (LMS) integrated with Project-Based Learning (PBL). Concept understanding data were collected through pretest and posttest tests. After implementation, students completed a practicality questionnaire assessing four dimensions: ease of use, suitability, time efficiency, and supporting features. Figure 2 summarizes the results, showing an average percentage of 89%, which falls into the very practical category.

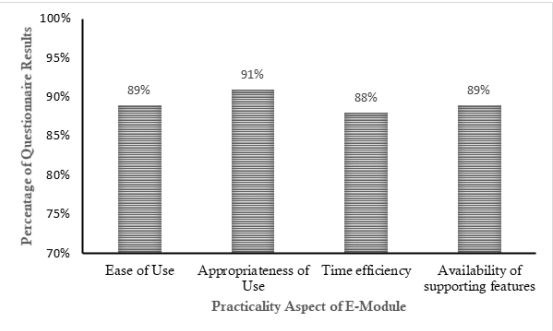


Figure 2. Recapitulation E-Module Practicality

Based on Figure 2, all aspects of practicality achieved an average percentage of 89%, indicating that the interactive e-module, based on LMS-integrated PjBL, is considered very practical by students. These results indicate that the e-module has met the criteria of practicality very well. According to Santosa (2024), the practicality of a learning media is reflected in its ease of use, efficiency in supporting the learning process, and suitability to user needs. Thus, this e-module has been proven to provide an efficient and relevant learning experience for students.

Based on the results of the normality test, the pretest and posttest data in the control class were not normally distributed. In contrast, the data in the experimental class were usually distributed. However, because the data did not meet the assumption of homogeneity, the analysis of increasing concept understanding in the experimental class was carried out using the Wilcoxon Signed-Rank Test, a non-parametric test, with the help of SPSS version 26 software (Sugiyono, 2019; Ghozali, 2016).

The Wilcoxon test results showed a significance value (Asymp. Sig. 2-tailed) of $p < 0.001$, indicating a statistically significant difference between the pretest and posttest scores following the implementation of the e-module. This improvement is also reflected in the normalized gain (N-gain) value of 0.75, which is classified in the high category (Hake, 1999). These results reinforce the findings that the use of interactive e-modules integrated with the PjBL approach can effectively improve students' concept understanding on the topic of alternative energy (Imamuddin, 2024; Resmanti et al., 2024; Syarofatin et al., 2022). Similar research also shows that the integration of PjBL in digital media can significantly encourage active involvement and conceptual understanding among students (Nieveen, 2010; Alya & Purwaningsih, 2025).

The effectiveness of the e-module was also analyzed by comparing the post-test results between the control and experimental classes. Because the post-test data were not normally distributed but homogeneous, the Mann-Whitney U test was used as an alternative to the t-test (Basuki & Nazarudin, 2015). The analysis results show the value of Asymp. Sig. (2-tailed) value of 0.001, which is smaller than the significance level of 0.05, indicating a significant difference between the two classes. The mean rank value of the experimental class of 39.19 is much higher than the control class of 13.81. This finding indicates that learning based on interactive e-modules integrated with PjBL is significantly more effective in improving student learning outcomes than conventional learning (Yulkifli et al., 2022; Rusmanto & Rukun, 2020; Febrianty et al., 2023). This aligns with the findings of Wally P (2024), who stated that a project-based approach in digital media can enhance students' understanding, independence, and learning achievement. To complement the statistical explanations presented above, the complete results of the research data analysis are summarized in Table 6. These results include the outcomes of the Wilcoxon Signed-Rank Test, N-gain analysis, and Mann–Whitney U Test,

which collectively provide an overview of the effectiveness of the developed interactive e-module.

Table 6. Summary of Research Data Analysis Results

Analysis Type	Statistical Test	Result	Interpretation
Improvement understanding in the Experimental Class	Wilcoxon Signed-Rank Test	p = 0.0001	Significant improvement
Learning gain	N-gain	0.75	High Category
Posttest Comparation (Control and Experiment	Mann-Whitney U Test	p = 0.001	Significant group difference
Mean Rank Different	Mann-Whitney U	Experimental = 39.19 Control = 13.81	Experimental class higher

The results summarized in Table 6 provide further confirmation of the statistical findings described earlier. All indicators consistently demonstrate that the interactive e-module integrated with PjBL is highly effective in improving students' conceptual understanding compared to conventional learning.

In addition to the concept understanding improvement test, an interactive e-module based on the LMS, integrated with PjBL, was implemented to increase independence. The aspects of independence in this study are as follows: being free to be responsible, progressive, and resilient, having initiative, self-control, and self-establishment (Widuroyekti et al., 2022). Independence data was obtained from questionnaires distributed to 26 experimental class students. The results of the data calculation using the Excel application yielded a percentage of 85% in the very independent category. This is in accordance with the research of Gunawan et al. 1 (2024) that the application of PjBl e-modules can increase student independence by 82.1%.

CONCLUSION

Based on the research results, the development of interactive e-modules based on the Learning Management System (LMS) integrated with the Project-Based Learning (PBL) model for alternative energy materials has met the theoretical and empirical feasibility criteria. The developed e-module obtained Aiken V scores of 0.94 for media and material validity, indicating a very high level of validity. The readability test results also show a percentage of 84.3%, which is classified as very good, so that students can easily understand this e-module. The implementation of e-modules in learning demonstrates significant effectiveness in improving students' conceptual understanding, as evidenced by a normalized gain (N-gain) value of 0.75 (high category) and the Wilcoxon test results, which show significance at the 0.001 level. Additionally, the improvement in learning outcomes is also evident from the significant difference between the experimental class and the control class, as indicated by the Mann-Whitney test results. In addition, the use of this e-module also contributed to an increase in student learning independence, with a percentage of 85%, and was considered very practical by students. Thus, the interactive e-module, based on LMS integrated with PjBL, is suitable for use as an alternative science learning medium that is contextual, effective, and supports the development of 21st-century skills.

The development of interactive e-modules based on LMS-integrated PjBL is recommended for wider application, both in other subjects and at different levels of education, to strengthen the transformation of innovative digital learning. Educators are expected to utilize this e-module as a teaching medium that not only delivers content but also forms critical, collaborative, and independent thinking skills in students. Future research is recommended to evaluate the long-term effectiveness of e-modules, as well as to integrate advanced technologies such as artificial intelligence and learning analytics to enhance personalization, adaptivity, and real-time monitoring of student learning processes.

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