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ORIGINAL RESEARCH

Development of a project-based electronic module to enhance students scientific literacy on sound wave concepts

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Abstract

This study aims to determine (1) the feasibility of a Project-Based Learning (PjBL) electronic module, (2) the implementation quality of learning using the module, and (3) the improvement of students' scientific literacy in a public senior high school in Bandung Regency. The research employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The population consisted of all Grade XI science students, with a sample of 34 participants. The instruments included expert validations (content, media, and practitioner), learning implementation observation sheets, and a scientific literacy test. Data analysis consisted of Aiken's V, implementation analysis, N-gain calculation, and a paired sample t-test. The findings indicate that the developed electronic module is highly feasible, with an Aiken's V index of 0.81. Learning implementation reached 84% for teacher activities and 86% for student activities, with an agreement coefficient of 0.79 (very good). The paired sample t-test yielded a significance value of 0.000 ($p < 0.05$), indicating a significant difference between pretest and posttest results. Students' scientific literacy improved with an N-gain score of 0.66, categorized as moderately effective. Overall, the PjBL-based electronic module is effective and can serve as an innovative learning medium to enhance scientific literacy at the senior high school level.

Keywords: Electronic Module · Padlet · Project-Based Learning (PjBL) · Scientific Literacy · Sound Waves

INTRODUCTION

Education in the twenty-first century emphasizes cognitive, social, emotional, and practical skills, including literacy, critical thinking, and scientific reasoning (Lubis et al., 2023). Scientific literacy, defined by OECD (2019) as the ability to apply knowledge, explain phenomena, and draw evidence-based conclusions, remains a global priority. Norris and Phillips (2003) further highlight its role in evaluating scientific issues in real-world contexts. Despite this importance, Indonesia's scientific literacy is still low. PISA 2022 showed improvement compared to 2018, yet performance remains below the global average (Hasanah, 2025), consistent with PISA 2018 data ranking Indonesia 74th of 80 countries (NCES, 2020). Contributing factors include teacher-centered approaches, limited innovative media, and insufficient contextual inquiry (Rusilowati et al., 2019).

The Merdeka Curriculum seeks to address these challenges by promoting flexible, interdisciplinary learning and encouraging digital, experimental, and project-based activities

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(Wahyudin et al., 2024; Putri et al., 2022; Muliaman et al., 2023). However, observations at a senior high school in Bandung Regency revealed passive student participation, reliance on lectures, and limited integration of PISA-aligned literacy. Diagnostic tests with 34 students on sound waves confirmed low performance across all indicators. Project-Based Learning (PjBL) offers a promising solution, supporting inquiry, collaboration, and problem-solving (Kamariah et al., 2023; Ridwan, 2024). When delivered digitally, e-modules provide interactive multimedia formats (Misdawati, 2023), and platforms like Padlet enhance engagement (Dewi et al., 2024). Sound waves, as abstract yet contextual phenomena, are sui Table for PjBL-based modules (Rahmawati et al., 2022). Previous studies (Rochmah, 2023; Mustika, 2022) revealed limitations in interactivity and inquiry, underscoring the need for accessible, engaging modules. This study develops a Padlet-based PjBL e-module on sound waves to examine its feasibility, classroom implementation, and effectiveness in improving students' scientific literacy.

METHODS

This study employed a Research and Development (R&D) approach to produce and evaluate an electronic module based on Project-Based Learning (PjBL). The development process followed the ADDIE model, which consists of the stages Analysis, Design, Development, Implementation, and Evaluation. In the Analysis stage, problems related to scientific literacy and the limitations of existing learning resources were identified through interviews, curriculum review, and diagnostic testing. During the Design stage, learning objectives, the module structure, multimedia components, and project-based activities were planned to align with PjBL principles and the characteristics of the sound wave topic. The research procedures is presented in Figure 1.

Figure 1. ADDIE Research Procedures

In the Development stage, the electronic module was created by integrating textual explanations, visual representations, interactive elements, and project instructions. The draft module was then reviewed by experts in content, media, and educational practice to obtain suggestions for refinement. The Implementation stage involved classroom use of the revised module with Grade XI students, accompanied by observations and pretest–posttest administration. Finally, in the Evaluation stage, the module was assessed for its feasibility and effectiveness, and necessary revisions were made based on expert validation results, classroom observations, and student learning outcomes.

The study collected both qualitative and quantitative data from primary and secondary sources. Qualitative data, obtained through expert reviews and observations, included comments, suggestions, and feedback from media experts, subject matter experts, and physics teachers regarding the feasibility and implementation of the PjBL-based electronic module. Quantitative data consisted of expert validation scores and students' scientific literacy results derived from pretest and posttest assessments. Primary data were gathered directly through classroom observations, interviews with physics teachers and students, and administration of scientific literacy tests to Grade XI science students. Secondary data were obtained from relevant literature, including articles, journals, and books related to electronic modules, project-based learning, and sound wave instruction.

Data for this study were collected through expert validation, classroom observation, and scientific literacy testing. The feasibility of the PjBL-based electronic module was assessed by a media expert, a content expert, and a physics teacher using structured validation questionnaires that evaluated content accuracy, presentation quality, language clarity, and media design. Their ratings, based on a five-point scale, were accompanied by comments and suggestions used to revise the module prior to implementation.

The implementation of learning with the electronic module was examined through observations conducted across four instructional sessions, during which two observers recorded the extent to which PjBL activities were carried out. Improvement in students' scientific literacy was measured using pretests and posttests consisting of twelve open-ended items aligned with PISA (2022) indicators of scientific literacy. All items were reviewed by experts to ensure validity, and the test results were used to determine students' learning gains after the intervention.

Data analysis was conducted to answer each research question and to determine the effectiveness of the developed PjBL-based electronic module. The feasibility of the module was assessed through expert validation data obtained from media experts, content experts, and a physics teacher. The experts' ratings were analyzed using Aiken's V to determine the content validity coefficient for each aspect of the module.

$$V = \frac{\sum S}{n(c-1)} \text{ where } S = r - l_0 \tag{1}$$

(Aiken, 1985: 135)

The interpretation of the content validity results of Aiken's V has been simplified by Koestoro & Basrowi (2006: 142) as in Table 1.

Table 1. Aiken's V Formula Score Range Category

Range	Category
0,8 – 1	Very High
0,6 – 0,799	High
0,4 – 0,599	Fair
0,2 – 0,399	Low
<0,2	Very Low

This approach enabled the identification of items that adequately represented the constructs being measured, with validity values ranging from 0 to 1. The results of this analysis served as the basis for determining whether the module met the criteria for a feasible learning product.

The implementation of learning using the electronic module was analyzed through observation data collected during four instructional meetings. Each observation sheet recorded whether planned activities were implemented, and the percentage of implementation was calculated for both teacher and student activities. Mean implementation scores across meetings were then compared with established interpretation criteria to determine the category of implementation quality.

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$$NP = \frac{obtained\ score}{overall\ score} \times 100\% \quad (2)$$

The average percentage criteria for learning achievement are presented in Table 2.

Table 2. Learning Implementation Criteria

Learning implementation criteria	Interpretation
≤ 54%	Very Poor
55% - 59%	Poor
60% - 75%	Fair
76% - 85%	Good
86% - 100%	Very Good

(Sari, 2020: 222)

Inter-rater agreement between the two observers was also examined using the Kappa coefficient to ensure consistency and reliability of the observational judgments.

$$S_k = \frac{P_o\text{-}P_e}{1\text{-}P_e} \quad (3)$$

(Nazaretsky et al., 2019: 130)

Napitupulu (2015: 74) has simplified the Kappa agreement criteria referring to Fleis (1981) as in Table 3.

Table 3. Kappa Interpretation

Criteria	Interpretation
< 0,40	Poor
0,40 – 0,60	Fair
0,60 – 0,75	Good
> 0,75	Very Good

Students' improvement in scientific literacy was examined through their performance on pretests and posttests, which consisted of open-ended items aligned with PISA scientific literacy indicators. Improvement scores were analyzed using normalized gain (N-Gain) to determine the magnitude of learning gains after the intervention. The classification of N-Gain values allowed the categorization of learning improvement into low, medium, or high.

$$\text{N-gain} = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}} \quad (4)$$

The results of the N-gain values obtained are then interpreted as in Table 4.

Table 4. N-gain Value Criteria

Normalized Gain Value	Interpretation
$g < 0,3$	Low
$0,3 \leq g < 0,7$	Medium
$g \geq 0,7$	High

(Hake, 1998: 65)

Prior to testing the effectiveness statistically, a normality test using the Shapiro–Wilk method was conducted to evaluate whether the data met parametric assumptions. Because the data were normally distributed, the paired sample t-test was employed to determine whether the difference between pretest and posttest scores was statistically significant. The significance level of 0.05 was used as the decision threshold for hypothesis testing.

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The study was conducted at a public senior high school in Bandung Regency, Indonesia. The participants consisted of 34 Grade XI science students selected through purposive sampling based on the recommendation of the physics teacher and the suitability of the learning schedule. The research was carried out during the 2024/2025 academic year in a regular classroom setting.

RESULT AND DISCUSSION

Analyze

The analysis stage revealed that the implementation of the Merdeka Curriculum in grade XI science classes requires students to apply sound wave concepts in everyday contexts. However, classroom observations showed that learning relied heavily on conventional printed modules, textbooks, and teacher-centered methods, which limited interactivity and resulted in passive student engagement. Interviews with teachers confirmed that scientific literacy had not been fully integrated into instruction, with low student motivation emerging as a persistent challenge. Students likewise reported limited exposure to scientific literacy and difficulties in understanding physics formulas, indicating a gap between curricular expectations and classroom practices.

Diagnostic testing further highlighted this gap, with students achieving an average literacy score of only 29.6 across competencies of explaining phenomena, designing investigations, and interpreting data. These findings underscored the need for innovative learning strategies that could foster active participation and strengthen literacy skills. Considering the widespread availability of smartphones among students, the development of interactive, project-based electronic modules was identified as a promising solution to enhance engagement and improve scientific literacy in the study of sound waves.

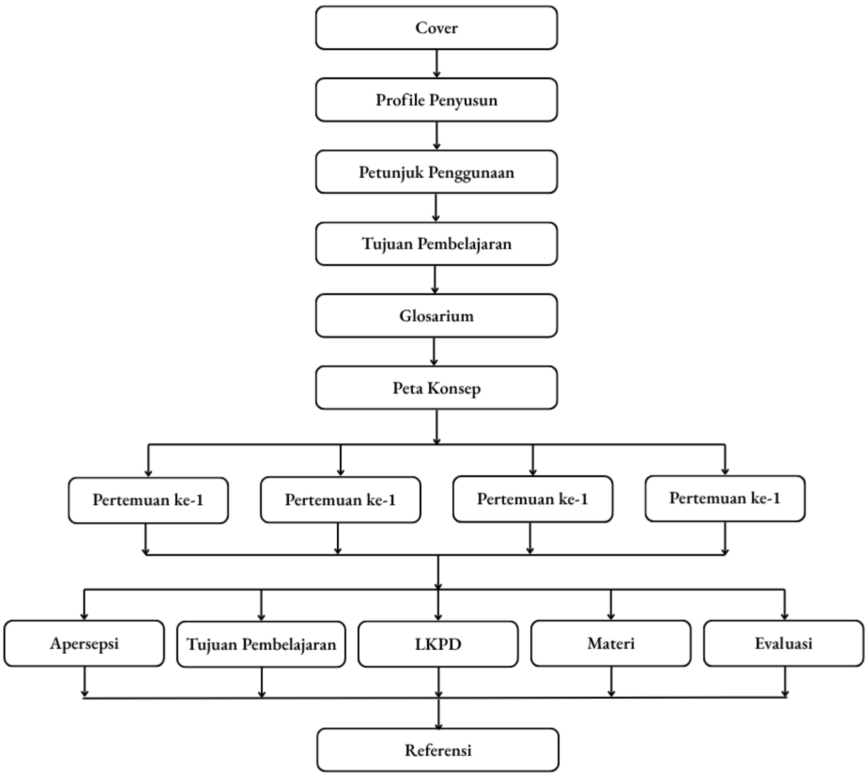

Figure 2. PjBL-Based Electronic Module Flowchart

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Design

At the design stage, the electronic module was structured through flowcharts and storyboards to ensure clarity and ease of use, with access provided via Padlet links on students' smartphones. The module integrated project-based worksheets (LKPD) and observation sheets through Google Forms to monitor implementation. Validation instruments for media and content were prepared and reviewed by experts and teachers, while pretest and posttest tools were designed to measure cognitive learning outcomes, ensuring the module's feasibility and pedagogical soundness.

Development

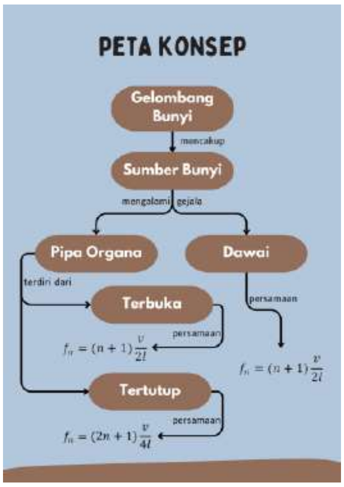
The development stage produced the electronic module based on Project-Based Learning (PjBL), designed using Canva and Padlet to integrate multimedia elements such as images, videos, and interactive worksheets. The module included key components such as cover, user guide, learning objectives, glossary, concept maps, and structured learning activities supported by student worksheets (LKPD) and evaluation tasks, all aligned with PjBL syntax to foster scientific literacy. The following shows some illustrations of the appearance of the electronic module that was developed.

Cover

User Guide

Learning Objectives

Glossary



Concept Maps

Reference

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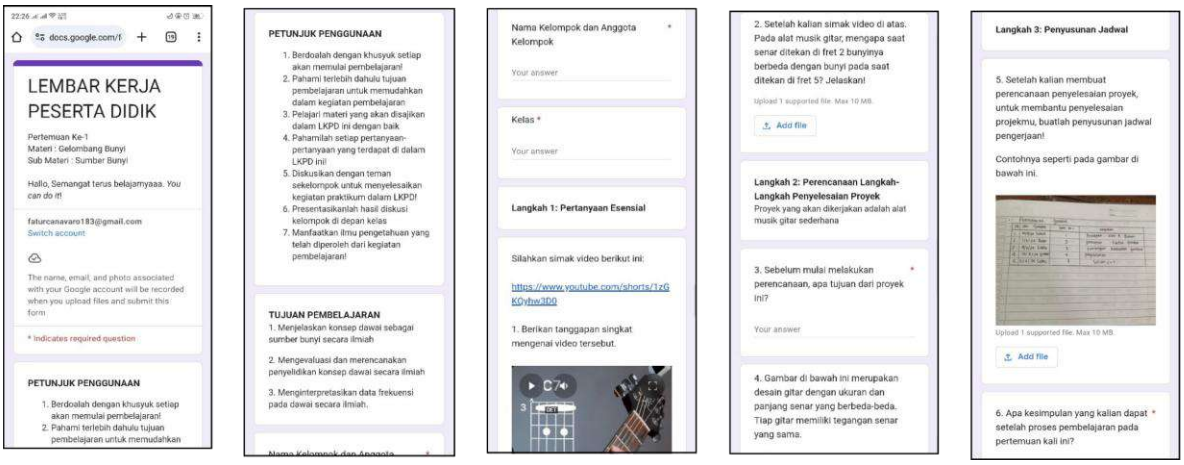
Learning Activity Design

Display After Clicking



LKPD Content Display

Figure 3. PjBL-based Electronic Module

Feasibility testing was conducted through expert validation. Media experts rated the module highly, with an average Aiken's V score of 0.83, indicating strong quality in language, presentation, instructional effectiveness, and visual design, though some aspects such as consistency of language and visual coherence were moderate. The results can be seen in Table 5.

Table 5. Media Expert Validation Results

Aspect	Score		V-Value	Interpretation
	Media Expert 1	Media Expert 2		
Feasibility of language aspects	4,5	4,2	0,835	High
Feasibility of presentation aspects	4,7	4,0	0,837	High
Media Effects on Learning Strategies	4,6	4,0	0,828	High
Feasibility of overall presentation	4,6	4,0	0,831	High
Average	4,6	4,0	0,833	High

Content experts provided a mean score of 0.79, confirming the accuracy, relevance, and pedagogical suitability of the material, while suggesting refinements in clarity, coherence, and contextual presentation. The results can be seen in Table 6.

Table 6. Content Expert Validation Results

Aspect	Score		V-Value	Interpretation
	Content Expert 1	Content Expert 2		
Content suitability	4,3	4,2	0,800	High
Presentation suitability	4,3	4,3	0,815	High
Language suitability according to BSNP	4,1	4,0	0,768	High
Contextual assessment	4,0	4,0	0,750	High
Average	4,2	4,1	0,783	High

Based on this feedback, revisions were made to improve formatting, glossary arrangement, learning objectives, and group work instructions. Overall, the module was judged feasible and appropriate for classroom implementation, with minor adjustments enhancing its effectiveness.

Implementation

The implementation stage was conducted after the analysis, design, and development phases were completed, with the electronic module based on Project-Based Learning (PjBL) applied in four classroom sessions. The module was used in class XI-9 at SMAN 2 Majalaya with 34 students between May 19 and May 28, 2025. Each session followed the PjBL syntax, beginning with start with the essential question, design a plan for the project, create a schedule, monitor the students and the progress of the project, assess the outcome, evaluate the experience.

Table 7. Percentage of Learning Implementation During Four Meetings

No	Learning Stage	Teacher Activities (%)	Student Activities (%)	Average per Stage (%)	Interpretation
1	Introduction	94	92	93	Very Good
2	Start With the Essential Question	100	100	100	Very Good
3	Design a Plan for the Project	100	100	100	Very Good
4	Create a Schedule	100	100	100	Very Good
5	Monitor the Students and the Progress of the Project	100	85	92	Very Good
6	Assess the Outcome	100	100	100	Very Good
7	Evaluate the Experience	100	100	100	Very Good
8	Closing	94	98	96	Very Good
Average		98	97	98	Very Good

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Observations and student worksheets (LKPD) were employed to evaluate the learning process. Based on Table 7, results consistently showed high levels of implementation, with teacher activities averaging above 90% and student participation ranging from "good" to "very good."

Agreement between observers, measured using Cohen's Kappa, indicated strong reliability across all sessions. Overall, the implementation confirmed that the electronic PjBL module effectively fostered active participation, critical thinking, and scientific literacy, making it feasible for broader application in physics learning on sound waves. Refer to Table 8 for a detailed summary of interobserver agreement coefficient across four meetings.

Table 8. Interobserver Agreement Coefficient Across Four Meetings

Symmetric Measures					
		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.795	.054	11.280	.000
N of Valid Cases		200			

Based on Table 8, the calculation of the interobserver agreement coefficient using Cohen's Kappa shows a value of 0.795, which indicates a significant agreement between the two observers regarding the observation results of learning implementation. Referring to Table 3, this value falls into the 'Very Good' category as it lies within the range >0.75. This category suggests that the differences in subjectivity between the observers are minimal, resulting in perceptions of the learning implementation that are generally uniform and consistent.

Evaluation

The evaluation stage assessed the effectiveness of the electronic module based on Project-Based Learning (PjBL) in improving students' scientific literacy on the topic of sound waves.

Table 9. N-gain Pretest and Posttest Results

Nilai Rata-rata		*N-Gain*	*Interpretasi*
Pretest	***Posttest***		
32,11	74,75	0,63	Middle

Pretest and posttest results from 34 students showed a significant increase, with average scores rising from 32.11 to 74.75 and an N-gain of 0.63, categorized as moderate. Individual analysis revealed that 62% of students achieved moderate improvement and 38% reached high improvement, while none remained in the low category, indicating that the module successfully minimized learning gaps (see Table 10).

Table 10. N-gain Results for Each Category

Category	Total	Persentage
High	13	38%
Middle	21	62%
Low	0	0%

Further analysis by literacy indicators demonstrated substantial progress. Based on Table 11, explaining scientific phenomena reached a high category (N-gain = 0.80), while evaluating and designing scientific investigations (0.52) and interpreting data and evidence (0.57) were in the moderate category.

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Table 11. N-Gain, Pretest and Posttest Results Based on Science Literacy Indicators

No.	Science Literacy Indicators	Question Number	*Pretest*	*Posttest*	*N-gain*	Interpretation
1	Explaining phenomena scientifically	1,4,7,10	36,03	87,50	0,80	High
2	Valuating and designing scientific inquiry	2,5,8,11	32,54	67,83	0,52	Middle
3	Scientifically interpreting data and evidence	3,6,9,12	27,76	68,93	0,57	Middle
Average			32,11	74,75	0,63	Middle

Subtopic analysis also confirmed consistent improvement across the 'string' and 'organ pipe' materials, both yielding moderate gains with an average N-gain of 0.63. See Table 12.

Table 12. N-Gain, Pretest and Posttest Results for Each Subtopic

No	Subtopic	Question Number	*Pretest*	*Posttest*	*N-gain*	Interpretation
1	String	1,3,6,7,10	35,29	80,88	0,69	Middle
2	Organ Pipe	2,4,5,8,9,11,12	29,83	70,38	0,58	Middle
Average			32,56	75,63	0,63	Middle

Statistical testing using paired sample t-test validated these findings, showing a significant difference between pretest and posttest scores ($t = 26.67$, $p < 0.001$). These results confirm that the electronic PjBL module effectively enhanced students' conceptual understanding, critical thinking, and overall scientific literacy, making it a feasible and impactful instructional innovation.

Table 13. Hypothesis Test Results with Paired Sample T-test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Posttest - Pretest	42.76471	9.34866	1.60328	39.50280	46.02661	26.673	33	.000

DISCUSSION

Feasibility of the Project-Based Learning (PjBL) Electronic Module

The development of the electronic module based on Project-Based Learning (PjBL) was aimed at improving students' scientific literacy in the topic of sound waves. This research adopted the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation.

At the analysis stage, observations and interviews revealed that learning was dominated by conventional printed modules, teacher-centered methods, and limited use of technology. Students expressed the need for more modern, accessible, and engaging media, while diagnostic testing confirmed that their initial literacy level was low, averaging only 29.6%. These findings justified the development of an electronic module designed to provide interactive and contextual learning experiences. The results showed that the module could serve as an effective solution to improve students' understanding of sound wave concepts and foster scientific thinking skills. This finding is consistent with Kamariah et al. (2023: 211–213), who reported that Project-Based Learning is effective in enhancing scientific literacy due to its alignment with learning demands.

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During the design stage, the module was structured with components such as cover, glossary, concept maps, user guide, learning materials, student worksheets (LKPD), evaluation tasks, and references. The module was aligned with three indicators of scientific literacy according to PISA (2022), namely: explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting data and scientific evidence. The platform chosen was Padlet, due to its interactive nature and accessibility, while Google Forms supported pretest, posttest, and worksheet completion. Julaidar et al. (2024: 99–100) emphasized that such structuring of electronic modules is essential to support project-based learning objectives.

In the development stage, the module underwent validation by experts in media, content, and classroom practice. Media validation produced an Aiken's V score of 0.83, categorized as high, indicating strong feasibility in language clarity, presentation, instructional effectiveness, and visual design. The language was considered clear and appropriate, capable of stimulating curiosity, and consistent throughout the module. Sitanggang et al. (2023: 1538) highlighted the importance of clear language in improving learning effectiveness. The presentation of content was systematic and coherent, supporting student engagement, although some aspects such as worksheet instructions and formatting required refinement.

Material validation yielded an Aiken's V score of 0.76, categorized as moderate but still feasible. The content was judged relevant and accurate, with strengths in its ability to stimulate curiosity and present updated material. The highest scores were obtained in indicators of material currency and encouragement of curiosity (V = 0.81). Experts suggested improvements in the coherence of conceptual flow, the inclusion of more contextual phenomena from everyday life, and refinement of summaries to strengthen comprehension. Trilling & Fadel (2009: 53) note that curiosity is a key characteristic in 21st-century learning, while Oksa & Soenarto (2020: 110) argue that modules with updated and engaging content can increase active involvement and deeper conceptual understanding. Sapata (2024: 21) also found that electronic modules developed with attention to content, language, and graphic design received highly positive responses, indicating strong potential to improve learning quality.

Implementation of Learning Using the Electronic Module Based on PjBL

The implementation of learning using the electronic module based on Project-Based Learning (PjBL) was carried out over four meetings with students of class XI-9 at SMAN 2 Majalaya. Pretest and posttest were administered to measure students' scientific literacy before and after the intervention, while observations and student worksheets (LKPD) were analyzed to evaluate the quality of implementation. Overall, the results showed consistently high levels of implementation, with average teacher activity at 98% and student activity at 97%. These findings indicate that the module was successfully integrated into classroom practice and fostered active participation. The interactive and engaging nature of the media contributed significantly to students' enthusiasm and comprehension, in line with Rikani et al. (2021: 7), who emphasized that attractive learning media can positively impact students' understanding and improve the overall quality of learning.

During the first meeting, students engaged with the concept of string instruments as sound sources. Observation results showed teacher activities at 100% and student activities at 97%, with Cohen's kappa indicating very strong agreement among observers. LKPD analysis revealed that essential questions scored 65% (categorized as sufficient), project planning 78%

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(good), and scheduling 94% (very good). The average score was 79%, categorized as good. These results highlight the importance of essential questions as the foundation of PjBL. Thomas (2000: 3) noted that essential questions are key triggers for inquiry, while Krajcik & Blumenfeld (2006: 323) emphasized that project planning fosters systematic thinking and collaboration. Prastika, M. D., et al. (2019: 192) also found that PjBL enhances students' ability to plan and organize projects collaboratively. The strong performance in scheduling reflects students' ability to manage time effectively, consistent with Moursund (1999: 46) and Saputra, M. I. (2024: 128), who highlighted the role of scheduling in teaching responsibility and discipline.

In the second meeting, students completed their first project and presented their results. Teacher activities were rated at 100% and student activities at 98%, with Cohen's kappa again showing strong agreement. However, LKPD scores were lower, with project completion under teacher facilitation at 68% (sufficient), reporting and presentation at 62% (sufficient), and evaluation at 68% (sufficient), yielding an average of 66%. These results suggest that students required more guidance in communication and reflection. Bell (2010: 40) identified facilitation balance as a challenge in PjBL, while Krajcik & Blumenfeld (2006: 328) stressed the importance of presentation and publication in developing scientific communication skills. Im, R., et al. (2025: 2487) similarly found that students need repeated practice to improve reporting and presentation abilities. Thomas (2000: 8) and Prastika, M. D., et al. (2019: 192) emphasized that evaluation stages are critical for reflection and improvement.

The third meeting focused on organ pipes as sound sources. Teacher activities were rated at 92% and student activities at 96%, with Cohen's kappa at 0.878, categorized as very strong agreement. LKPD scores improved significantly, with essential questions at 97%, project planning at 88%, and scheduling at 87%, yielding an average of 90% (very good). This improvement reflects students' growing familiarity with PjBL syntax. Rizkasari, E., et al. (2022: 14515) noted that project-based learning is cumulative, with skills improving through repeated practice. Prapsetyo, A. M. D. L., et al. (2025: 1) confirmed that frequent project involvement sharpens critical thinking, collaboration, and problem-solving skills. However, scheduling showed slight decline due to time constraints, consistent with Thomas (2000: 33–34), who highlighted time management as a common challenge in PjBL.

In the fourth meeting, students completed their second project using organ pipes. Teacher activities were rated at 97% and student activities at 94%, with Cohen's kappa at 0.790, again showing strong agreement. LKPD scores were high, with project completion at 88% (very good), reporting and presentation at 85% (good), and evaluation at 100% (very good), yielding an average of 91% (very good). These results demonstrate that students became more adept at collaboration, communication, and reflection. Swastika, A. I., & Utami, I. (2025: 71) explained this improvement through Vygotsky's scaffolding concept, where initial teacher guidance enables students to gradually work more independently. Prastika, M. D., et al. (2019: 192) also found that gradual application of PjBL enhances consistency and learning outcomes.

Overall, the implementation of the electronic module based on PjBL was highly successful, with strong teacher facilitation and active student participation across all meetings. The highest implementation scores were achieved in project planning and scheduling, both at 100%, reflecting systematic preparation and effective guidance. Thomas (2000: 5) emphasized that thorough planning is a hallmark of PjBL, while Menrisal, M., et al. (2019: 8) found that electronic modules help students understand project steps more efficiently. Presentation and

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evaluation stages also achieved excellent results, confirming the importance of communication and reflection in PjBL. Krajcik & Blumenfeld (2006: 328), Im, R., et al. (2025: 2487), and Thomas (2000: 8) all highlighted these stages as essential for scientific literacy development. The overall findings are consistent with Bell (2010: 43), Mutia et al. (2025: 42), and Hidayatullah et al. (2025: 28), who reported that PjBL increases motivation, responsibility, and participation, while strengthening teacher activity and student engagement.

Improvement of Students' Scientific Literacy

The evaluation of students' scientific literacy was conducted through pretest and posttest assessments on sound waves, designed around three indicators: explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence. Teachers clarified each item to ensure comprehension (Setiani et al., 2022: 2295). The average N-gain was 0.66, categorized as moderate, confirming the effectiveness of the electronic PjBL module. This finding is consistent with Saprudin et al. (2021: 38–39), who reported that electronic modules in physics education can significantly enhance literacy skills and foster independent learning. Similarly, Muzijah et al. (2020: 96) emphasized that electronic physics modules are practical to implement and have strong potential to develop students' literacy skills.

Individual analysis showed that all students experienced improvement, with none in the low category. Of the 34 students, 62% achieved moderate gains and 38% reached high gains. The strongest improvement was in explaining phenomena (N-gain = 0.80, high), consistent with Ihsan & Jannah (2021: 197), while evaluating and designing investigations (0.52) and interpreting data (0.57) were moderate, reflecting challenges noted by Juliani et al. (2017: 1). Subtopic analysis revealed moderate gains in strings (0.69) and organ pipes (0.58), with the latter lower due to weaker contextual links, as emphasized by Andini et al. (2022: 74). These findings highlight the importance of contextual approaches, consistent with Kamariah et al. (2023: 213), who confirmed that project-based learning enhances literacy and creativity.

To validate these improvements statistically, hypothesis testing was conducted. Normality testing using Shapiro–Wilk confirmed that both pretest ($p = 0.240$) and posttest ($p = 0.554$) data were normally distributed, meeting the assumptions for parametric analysis (Shapiro & Wilk, 1965: 591). With this prerequisite satisfied, a paired sample t-test was applied, yielding a highly significant difference between pretest and posttest scores ($t = 26.673$, $p < 0.05$). Rahmani, D. A., et al. (2025: 570) emphasized that paired sample t-tests are valid and appropriate when data are normally distributed, as they clearly capture differences between conditions measured at different times.

The results confirm that the electronic PjBL module significantly improved students' scientific literacy. Savitri et al. (2024: 142) found that interactive media such as Padlet play an important role in enhancing literacy by facilitating access and encouraging active engagement. This aligns with the present findings, where the t-value of 26.673 far exceeded the critical t-Table value of 2.035, demonstrating substantial improvement. Azhari (2024: 47) similarly reported that interactive and engaging technology-based learning media enhance literacy and cognitive skills.

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CONCLUSION

This study at SMAN 2 Majalaya focused on developing a Padlet-based electronic module adopting Project-Based Learning (PjBL) to enhance students' scientific literacy in sound waves. The module was systematically designed, validated, and implemented through the ADDIE model. Validation results showed high feasibility (Aiken's V = 0.81), confirming the module's validity and suitability as an alternative learning medium. Classroom implementation demonstrated strong effectiveness, with teacher activities averaging 84% and student activities 86%, both in the "very good" category. Scientific literacy improved significantly, as indicated by an average N-gain of 0.63 (moderate) and hypothesis testing results ($t = 26.673$, $p < 0.05$), which confirmed a meaningful difference between pretest and posttest scores.

Based on these findings, further development of PjBL-based electronic modules should enrich project activities with more contextual and everyday relevance. Schools are encouraged to provide technical training for teachers in using design platforms such as Canva and Padlet to create interactive media, including features like experimental videos, automated quizzes, and discussion forums. Regular reflection and evaluation are recommended, particularly in the "Essential Question" and "Evaluation" stages, as they strongly influence learning outcomes. Peer mentoring can also support students facing difficulties and foster collaboration. Finally, since the lowest N-gain was found in evaluating and designing scientific investigations, strengthening this skill through systematic inquiry tasks, mini-research projects, and guided experiments is essential to cultivate critical and independent scientific thinking.

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