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Needs Analysis of STEM-PBL E-Modules Integrating Papuan Local Wisdom to Support Critical Thinking and Creativity in Sound Wave Learning

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ABSTRACT

Physics learning in secondary schools still faces obstacles in developing students' critical thinking skills and creativity, especially due to the limitations of digital teaching materials that are contextual and integrated with local wisdom. This study aims to analyze the needs, implementation constraints, and perceptions of physics teachers towards the development of STEM-PBL e-modules based on Papuan local wisdom on sound wave materials. This study is a needs analysis study at the Analyze stage in the ADDIE model with a mixed method approach through a descriptive survey. The subjects of the study were 11 high school physics teachers in Merauke Regency who were selected purposively. Data were collected through Likert scale questionnaires and interviews, then analyzed quantitatively-descriptively and qualitative-thematic. The results of the study showed that as many as 81.82% of teachers were interested in developing modules containing local wisdom, 84.09% had used experimental methods, and 75.00% had implemented PBL. However, there is a gap between interest and implementation capacity, where 63.64% of teachers have difficulty developing modules with local wisdom, only 52.27% apply STEM-PBL in an integrated manner, and the integration of local wisdom is still partial even though 93.18% of teachers consider sound wave material as an essential topic. Based on the teacher's perspective, the need for STEM-PBL e-modules based on Papuan local wisdom arises from the gap between the learning practices that have taken place and the demands of integrated contextual learning implementation. These findings show the need to develop e-modules that provide systematic STEM-PBL integration, relevant Papuan cultural contexts, and pedagogical guidance that can support teachers in implementing sound wave learning in a more structured and meaningful way.

INTISARI

Pembelajaran fisika di sekolah menengah masih menghadapi kendala dalam mengembangkan keterampilan berpikir kritis dan kreativitas siswa, terutama karena keterbatasan bahan ajar digital yang kontekstual dan terintegrasi dengan kearifan lokal. Penelitian ini bertujuan menganalisis kebutuhan, kendala implementasi, dan persepsi guru fisika terhadap pengembangan e-modul STEM-PBL berbasis kearifan lokal Papua pada materi gelombang bunyi. Penelitian ini merupakan studi analisis kebutuhan pada tahap Analyze dalam model ADDIE

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dengan pendekatan mixed method melalui survei deskriptif. Subjek penelitian adalah 11 guru fisika SMA di Kabupaten Merauke yang dipilih secara purposive. Data dikumpulkan melalui angket skala Likert dan wawancara, kemudian dianalisis secara kuantitatif-deskriptif dan kualitatif-tematik. Hasil penelitian menunjukkan sebanyak 81,82% guru tertarik mengembangkan modul bermuatan kearifan lokal, 84,09% telah menggunakan metode eksperimen, dan 75,00% telah menerapkan PBL. Meskipun demikian, terdapat kesenjangan antara minat dan kapasitas implementasi, di mana 63,64% guru kesulitan mengembangkan modul bermuatan kearifan lokal, hanya 52,27% yang menerapkan STEM-PBL secara terpadu, dan integrasi kearifan lokal masih bersifat parsial meskipun 93,18% guru menilai materi gelombang bunyi sebagai topik esensial. Berdasarkan perspektif guru, kebutuhan terhadap e-modul STEM-PBL berbasis kearifan lokal Papua muncul dari adanya kesenjangan antara praktik pembelajaran yang telah berlangsung dengan tuntutan implementasi pembelajaran kontekstual yang terintegrasi. Temuan ini menunjukkan perlunya pengembangan e-modul yang menyediakan integrasi STEM-PBL secara sistematis, konteks budaya Papua yang relevan, serta panduan pedagogis yang dapat mendukung guru dalam mengimplementasikan pembelajaran gelombang bunyi secara lebih terstruktur dan bermakna.

A. Introduction

21st century education demands graduates who are able to think critically and creatively in the face of complex global challenges, especially in the realm of science and technology (Sukarmin & Sani, 2023; Yurdunkulu et al., 2025). However, data from the Programme for International Student Assessment (PISA) 2022 reveals that the average science achievement of Indonesian students is only 383 points, far below the OECD average of 485 points (OECD, 2023). Indonesia's creative thinking score of only 19 out of 60 is also far below the OECD average of 33 with only 31% of students reaching the basic level of creative (Level 3) compared to the average of 78% in other countries (OECD, 2024). This data indicates that higher-order thinking skills such as critical thinking and creativity in students in the context of science learning are an important cornerstone in the global curriculum of the 21st century. In this context, teachers' need for digital teaching materials that are contextual and support the development of high-level thinking skills in science learning is an important issue to be analyzed, especially in materials that have abstract concepts such as sound waves.

This problem is exacerbated by the fact that many teaching materials and learning media in secondary schools still use conventional approaches that lack real context and digitalization, thus lacking support for the development of higher-level thinking skills (Wijesekera & Hameed, 2026). The Science, Technology, Engineering, and Mathematics (STEM) approach combined with Problem-Based Learning (PBL) has been empirically proven to be able to improve students' critical thinking skills and creativity through authentic and real-world problem-based learning experiences (Dwiningsih et al., 2024; Pinar et al., 2025). Although these pedagogical elements

promise to improve the quality of learning, there are still many schools and teachers in Indonesia who do not have STEM-PBL-based digital learning media (e-modules) that are integrated with the local cultural context (Hudawati et al., 2024).

A number of studies have shown the effectiveness of developing STEM-PBL-based digital learning media and cultural contexts in improving students' thinking skills, but the focus of needs analysis is still limited (Arifin et al., 2021). One study found that a STEM-PBL-based e-module in the form of a digital flipbook boosted students' critical thinking and creativity on global warming material with high validity, practicability, and effectiveness (Ayu & Rosana, 2025). Other research emphasizes the importance of needs analysis in the development of ethno-STEM PBL e-modules for vibration, wave, and sound topics to make the modules more relevant and effective (Almira et al., 2025). Previous studies have also shown that interactive modules based on local wisdom have a positive impact on students' critical thinking when the context of the local culture is integrated into learning (Syahfitri, 2024).

Although a number of previous studies have conducted needs analysis on physics learning media and the integration of local wisdom. The research is generally qualitative, descriptive, with a wide scope (e.g., the integration of local wisdom in Bali or Bengkulu) and has not explored systematic quantitative needs analysis from the perspective of physics teachers as the main users of the media (emodule). Studies such as Needs Analysis of Physics Learning Media Integrated Local Wisdom show that the current learning media is inadequate and that teachers have not played an optimal role in the development of local wisdom-based media, but do not measurably assess the percentage of needs, constraints, and perceptions of physics teachers in certain contexts (Eliezanatalie & Deta, 2023). In addition, an international literature review on the integration of local wisdom in science learning shows that there are common obstacles such as the lack of documentation of cultural knowledge in learning media and the limited involvement of teachers in the material development process (Sihombing et al., 2025).

Papua is unique in that its cultural characteristics and local knowledge are culturally and ecologically different from other regions in Indonesia, so culturally relevant approaches and materials are also different (Fiharsono et al., 2026). Research on the development of local wisdom modules in Papua so far has largely focused on the development of science modules for early childhood or general material feasibility tests, without empirically assessing the needs of teachers or systematically incorporating STEMPBL components (Day et al., 2025).

This research fills a gap that has not been explored before, namely a quantitative and qualitative analysis of the needs of physics teachers for STEMPBL-based emodules that are integrated with local Papuan wisdom. The novelty of this research lies in the emphasis on the aspect of teacher needs as the basis for media design, the involvement of STEM and PBL components simultaneously, and the

contextualization of local Papuan wisdom which has not been widely used as an object of science learning material needs in international literature.

The material of sound waves was chosen as the focus of the research because this concept is abstract, but close to the daily phenomenon in the cultural life of the Papuan people. One example is Tifa, a traditional Papuan percussion instrument that produces sound through membrane vibration and tube chamber resonance. So it can be used to explain the concepts of frequency, amplitude, resonance, sound source, and wave propagation (Rai, 2019).

The integration of Tifa as a scientific context allows teachers to connect the concept of wave physics with students' cultural experiences, so that learning becomes more contextual, meaningful, and easy to understand. This approach is in line with culturally responsive science teaching, which emphasizes the use of students' cultural experiences as a learning resource in science learning (Wallace et al., 2022). In addition, the use of traditional musical instruments as a medium for learning sound waves has been reported to be able to present relevant cultural contexts and support students' understanding of physics concepts (Mustofa et al., 2021).

Therefore, this study aims to analyze the percentage of needs, implementation constraints, and perceptions of physics teachers in Merauke Regency. This research contributes to the provision of measurable data on teacher needs, recommendations for strategies for the development of STEM-PBL-based modules that are contextual with local cultures, and practical guidance for the implementation of innovative learning media in secondary schools, especially in multicultural areas such as Merauke. This research can also be used as a fundamental foothold at the analysis stage in the series of Research and Development (R&D) for the creation of the Physics E-Module.

B. Method

This study is a needs assessment study as the first stage (analyze) in the ADDIE (Analyze, Design, Develop, Implements, Evaluate) development method (Li et al., 2025). This study uses a descriptive survey with a mixed method approach, combining quantitative and qualitative data. This approach aims to gain a deeper understanding of the need for STEM-PBL e-modules that integrate local Papuan wisdom in sound wave learning in secondary schools. Descriptive surveys describe the current condition or situation of a group or phenomenon and are often the first step in research (Handayani et al., 2026). The mixed-methods approach offers the advantage of combining numerical data analysis with in-depth insights gained from interviews (Hadianto et al., 2021).

Specifically, this study uses a convergent parallel type mixed method design, namely quantitative data through a Likert questionnaire and qualitative data through interviews collected at the same stage, analyzed separately. Then the research data is integrated at the interpretation stage to obtain a more complete understanding of the

needs of teachers. This design was chosen because needs analysis research requires numerical data to map the level of teacher needs as well as qualitative data to explain the reasons, constraints, and context behind quantitative findings (Zhou et al., 2024). Data integration was carried out through a side-by-side comparison technique, which is to compare the results of descriptive statistics with relevant interview themes (Matović & Ovesni, 2023).

This study used purposive sampling techniques to select participants with specific characteristics relevant to the research objectives (Desnita et al., 2025). The research subjects consisted of 11 high school physics teachers in Merauke Regency, South Papua Province. The sample selection criteria will be described in table 1. The sample was selected through a purposive sampling technique with the criteria of teachers who actively teach sound wave material.

The number of 11 respondents was chosen because this study is needs analysis in the early stages of development of learning instruments, where a smaller but contextually representative sample can be adequate to identify patterns of needs, implementation constraints, and perceptions of the main media users. This approach is in line with some learning needs studies that use limited sample sizes for initial exploration and needs mapping because of their focus on specific contexts and in-depth quantitative qualitatives, rather than broad population generalizations (Flint-Taylor et al., 2023). Mixed method research with a sample of teachers ranging from 8–15 participants is often considered adequate for the initial descriptive needs and thematic analysis (Wutich et al., 2024). Especially when interview data is combined with quantitative survey data for triangulation of findings (Hagaman & Wutich, 2017).

However, the limited number of subjects means that the findings of this study are contextual for the Merauke region and cannot be generalized to the entire population of physics teachers in Indonesia. Therefore, the results of the needs analysis are used as an initial empirical basis for designing relevant modules, as well as recommendations for follow-up studies with a larger sample or multisite approach. Data collection was carried out online (Google Form) using two groups of instruments. The first instrument was a closed-ended questionnaire on the Likert scale (scores 1-4) consisting of 30 statements to measure seven aspects of need.

Before being used in data collection, the questionnaire instrument consisting of 30 Likert scale items and interview guidelines first went through a content validity process through expert judgment. The assessment process was carried out by Prof. Sukarmin, S.Pd., M.Si., Ph.D., Professor of Physics Education who has expertise in the field of physics learning development and educational evaluation. Expert validation is focused on the suitability of indicators with the research objectives, clarity of the editorial of the item, relevance of the construct, and the representation of the aspects measured in the analysis of the needs for the development of STEM-PBL e-modules based on local Papuan wisdom.

The use of expert judgment in the development of educational research instruments is a commonly used procedure to ensure the validity of the content before the instrument is implemented to respondents (Boateng et al., 2018). The validity of the content through expert assessment is considered adequate in the initial stage of development research (preliminary study) and needs analysis because it aims to ensure the suitability between indicators, constructs, and research context (Yusoff, 2019). In addition, in exploration-oriented needs research, expert validation is often used as a basis to guarantee the credibility of the instrument before further testing is carried out on a larger sample.

However, this study has limitations because it has not conducted internal reliability testing using Cronbach's Alpha coefficient given the relatively limited number of respondents. Therefore, the results of this study are positioned as preliminary findings that can be the basis for further development research with a larger sample number to test the psychometric characteristics of the instrument more comprehensively.

The data collection instruments used in this study consisted of teacher questionnaires and teacher interviews. The questionnaire was distributed directly to teachers to collect quantitative data on their perceptions and needs regarding the use of the STEM-PBL e-module that integrates local Papuan wisdom in sound wave learning. The Likert scale questionnaire (1-4) includes items that measure the use of teaching modules, learning processes, STEM-PBL approaches, deep learning, sound wave materials, as well as critical thinking skills and students' creativity skills.

Teacher interviews are conducted both face-to-face and through Google Meet to obtain qualitative data. This interview aims to explore the perspectives of physics teachers in Merauke Regency regarding their need for STEM-PBL e-modules that integrate local Papuan wisdom, the obstacles they face in the implementation of the modules, and their perceptions of the influence of modules on students' critical thinking skills and creativity in sound wave learning.

Table 1. Research Subject Criteria

Criteria	Operational Description	Eligibility Reasons
Teachers Profile	Active physics teacher at Public/Private High School in Merauke Regency	Ensure respondents have up-to-date teaching experience
Teaching Experience	Minimum of 2 years of teaching physics	Ensure familiarity with sound wave material and classroom dynamics
Materials Taught	Have or are teaching the topic of Sound Waves in the last 2 years	Direct relevance to the research focus
Use of Teaching Modules	Have used teaching modules (print and digital) in physics learning	Ensuring that respondents can meaningfully assess the needs of e-modules
Willingness to Participate	Willing to fill out an online questionnaire (Google Form)	Ethical and practical feasibility of data collection

Criteria	Operational Description	Eligibility Reasons
	and be interviewed (face-to-face/Google Meet)	
Teaching Location	The school is located in the administrative area of Merauke Regency, South Papua Province	Geographical focus on the context of local Papuan wisdom

C. Result and Discussion

Teaching Module Needs

The results of the needs analysis show that physics teachers in Merauke Regency have a high need for the development of STEM-PBL e-modules that integrate local Papuan wisdom.

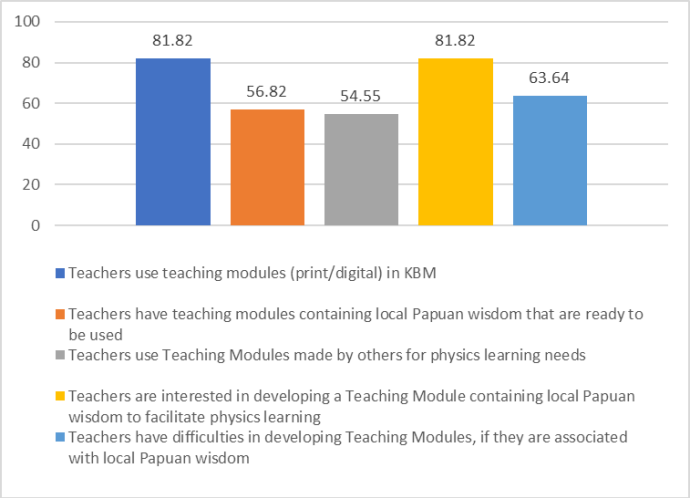

Figure 1. Teaching Module Needs Graph

The figure 1 shows that 81.82% of teachers have used teaching modules in learning, both print and digital. These findings indicate that the use of modules has become part of learning practices, so that the development of e-modules has good implementation opportunities.

However, the availability of modules that are appropriate to the local context is still limited. Only 56.82% of teachers stated that they had teaching modules containing Papuan local wisdom that were ready to be used. Meanwhile, 54.55% of teachers are still using modules made by other parties. This condition shows that even though teachers are used to using modules, teaching materials that are contextual and relevant to the local culture of Papua are still inadequate. In fact, the integration of local knowledge in science learning can make learning more meaningful, relevant,

and close to the student experience (Eitel et al., 2024; Solas-Martínez & Torre-Cruz, 2025).

Another important finding is that 81.82% of teachers are interested in developing teaching modules containing local Papuan wisdom to facilitate physics learning. This shows the positive perception of teachers towards teaching materials that connect the concept of physics with the local cultural context. These findings are in line with research that states that STEM, PBL, and local context-based learning can increase learning relevance and support creativity and problem-solving (Sumarni et al., 2021; Udyaningsih et al., 2024; Utari et al., 2024).

However, 63.64% of teachers admitted that they had difficulties in developing teaching modules that were associated with local Papuan wisdom. This shows that there is a gap between teachers' interests and implementation skills. These barriers may be related to limited references, training, examples of teaching materials, and the ability to relate local knowledge to science concepts. These findings are supported by studies that suggest that the integration of indigenous knowledge in STEM is often constrained by a lack of training, resources, and curricular guidance (Photo & McKnight, 2024; O'Donoghue et al., 2024).

Qualitative data also corroborate these findings. For example, one of the teachers stated: *"Integrating Papuan local wisdom into sound wave topics is challenging because there are limited references and examples of how local knowledge connects with physics concepts."* Other interviews also showed that limited references, training, and contextual guidance were the main obstacles in developing modules that utilized Papuan culture. This is in line with the study's findings that the contextualization of science based on local wisdom is often constrained by the lack of support of educational resources (Rosyidah et al., 2025).

In addition, the digital readiness of schools is a determining factor for the success of the implementation of e-modules. Schools with adequate digital infrastructure can facilitate the use of interactive modules, videos, and simulations, while network and device limitations can hinder STEM-PBL-based learning. Previous research confirms that the readiness of digital infrastructure has a great influence on the adoption of innovative learning technologies in schools (Roll & Ifenthaler, 2021).

Local culture as a scientific context also enriches learning. The integration of Papuan local wisdom is not just an illustration, but serves as an authentic scientific phenomenon, where students can relate the concept of sound waves to cultural practices such as traditional musical instruments or everyday activities. Contexts like this increase the relevance of the material, student engagement, and critical thinking and creativity skills.

The triangulation between quantitative and qualitative data reinforces the conclusion that the development of interactive and contextual e-modules is not only relevant, but also urgent to improve students' critical thinking skills and creativity through STEM-PBL-based soundwave learning. Thus, these results not only illustrate

statistical figures, but also emphasize the pedagogical implications: teachers need teaching materials that are culturally appropriate, interactive, and supportive *of active learning*, while module developers must provide adequate implementation guidance, training, and references to bridge the gap between needs and implementability capabilities.

Learning Process

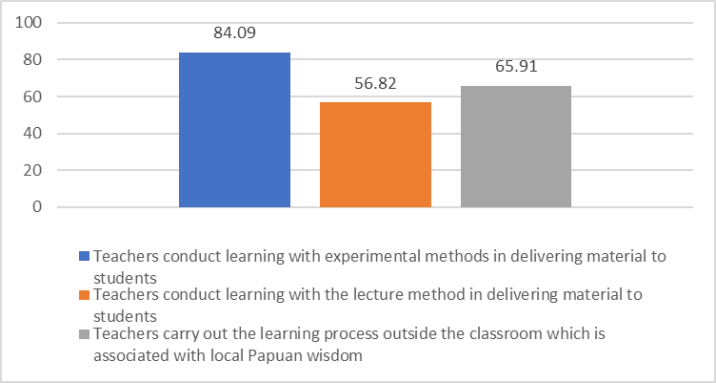

Figure 2. Learning Process Graph

The figure 2 show that the practice of physics learning in Merauke Regency has led to an active approach, but it has not been fully integrated with the context of local Papuan wisdom. Based on the graph, 84.09% of teachers have used experimental methods in learning. This suggests that most teachers have implemented a constructivist approach that emphasizes students' hands-on activities and empirical experiences. These findings are in line with the characteristics of STEM and PBL learning that emphasize exploration, investigation, and problem-solving as the core of the learning process (Liu, 2025).

However, 56.82% of teachers still use the lecture method , which shows that the teacher-centered approach is still quite dominant. This condition indicates an inconsistency between innovative and traditional learning practices. Previous studies have confirmed that the dominance of lecture methods tends to be less effective in developing critical thinking skills and creativity than problem- or project-based learning (Hudha et al., 2023). Therefore, a transformation is needed towards a more student-centered learning model such as STEM-PBL.

These findings indicate the dualism of learning practices, namely the use of active learning strategies that go hand in hand with a teacher-centered approach. The results of the interviews revealed that this condition was not solely caused by teachers' pedagogical preferences, but also influenced by limited learning time, demands for material completion, and limited learning resources that support project-based

learning. One teacher stated: *"In some topics, especially abstract physics concepts, I still rely on direct explanation because there are limited teaching materials that connect the concepts with students' real-life experiences and local contexts."*

The statement suggests that the use of lecture methods is often a practical strategy when teachers do not have adequate learning resources to facilitate more exploratory learning. Thus, the dominance of the lecture method is not only related to the pedagogic competence of teachers, but also related to the availability of teaching materials that are able to support contextual learning.

Furthermore, 65.91% of teachers have carried out learning outside the classroom which is associated with local Papuan wisdom. These findings suggest that some teachers have begun to integrate local contexts in learning, although not optimally. The integration of local wisdom in science learning has been proven to increase material relevance, student engagement, and concept understanding through contextual experiences (Kamila et al., 2024; Matindike & Ramdhany, 2025).

The results of the interviews also showed that teachers used the surrounding environment and local cultural phenomena as examples in explaining physics concepts. One of the respondents explained: *"Students become more interested when physics concepts are connected to local cultural practices, but it is difficult to find structured materials that explain the scientific principles behind those practices."*

However, this percentage shows that the integration of local wisdom is still partial and has not been structured in the form of systematic teaching materials such as e-modules. Previous research confirms that the integration of planned local wisdom in STEM-based e-modules or PBL is more effective in improving students' critical thinking skills and creativity (Putri & Turaqulov, 2022; Naurah Nazifah, 2024).

Triangulation between quantitative data and interviews shows that experimental practice, contextual learning, and teachers' interest in the integration of local wisdom have actually become strong foundations for STEM-PBL implementation. However, the limitations of structured teaching materials cause the practice to not develop into consistent and sustainable learning.

The educational implication of these findings is that the development of STEM-PBL e-modules based on Papuan local wisdom has the potential to be a bridge between the learning practices that teachers have carried out with the demands of 21st century learning. Through the provision of project-based activities, authentic issues, and cultural contexts that are close to students' lives, e-modules can help teachers reduce their reliance on lecture methods while strengthening the development of critical thinking skills and creativity in a more systematic manner.

STEM-PBL Learning

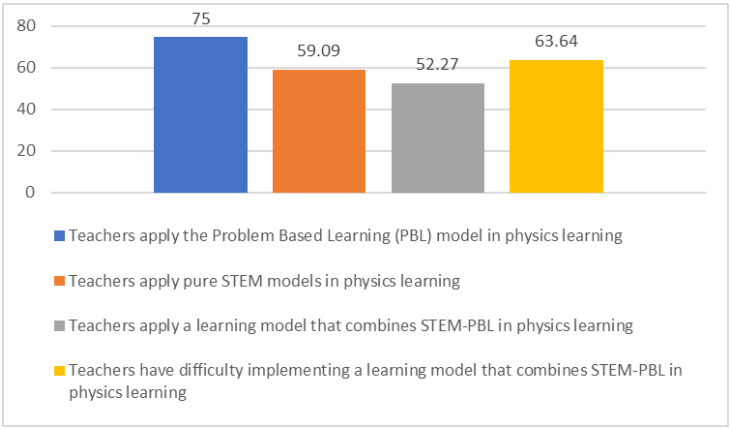

Figure 3. STEM-PBL Learning Graph

The figure 3 show that 75.00% of teachers have implemented Problem Based Learning (PBL) in physics learning. This percentage shows that PBL is relatively well known and used in learning practices. These findings are important because PBL is an approach that places contextual problems as a learning trigger, making it relevant to encourage students' critical thinking and problem-solving skills (Hudha et al., 2023; Liu, 2025).

Meanwhile, 59.09% of teachers have implemented the pure STEM model, but only 52.27% of teachers have implemented the STEM-PBL integrated learning model. This data shows that the integration of STEM and PBL is not yet the dominant practice, although each approach has already begun to be used. This condition indicates that teachers are still more familiar with the application of the model separately than the integrated model. The qualitative data further explains why integration has not been maximized. One teacher explained: *"I had a hard time designing integrated STEM-PBL learning because I didn't have the examples and time to prepare problems that connect science, technology, and local contexts simultaneously."*

This quote points to a systemic problem: limited access to contextual learning examples, professional training, and integrated learning resources. These findings are in line with research that emphasizes that teacher readiness, not just awareness, is a key factor in the success of STEM integration, and that a lack of pedagogical support often hinders implementation even when teachers have a positive attitude (Vaiopoulou et al., 2024).

In fact, research shows that STEM-PBL integration is more effective in building creativity, problem-solving, and learning engagement because it connects scientific

inquiry, design, and authentic problem-solving simultaneously (Sumarni et al., 2021; Naurah Nazifah, 2024).

On the other hand, 63.64% of teachers stated that they had difficulty applying the STEM-PBL model to physics learning. These findings show that the obstacles to implementation are still quite high, even exceeding the percentage of teachers who actually implement them. These difficulties may be related to the complexity of designing learning syntax, the development of contextual problems, the integration of STEM across disciplines, and the limitations of supporting teaching materials. Previous studies have also shown that the implementation of innovative STEM-based learning and local knowledge is often hampered by a lack of training, exemplary teaching tools, and adequate pedagogical support (O'Donoghue et al., 2024; Matindike & Ramdhany, 2025).

Teachers' difficulties in implementing STEM-PBL not only show the low frequency of use of integrated models, but also reflect the pedagogical complexity of integrated STEM learning. The STEM-PBL model requires teachers to be able to design authentic problems, connect science concepts with technology, engineering, and mathematics, and manage students' investigative processes in one coherent learning flow (Tytler et al., 2023). This complexity is often an obstacle because teachers need cross-disciplinary understanding, problem-based learning design skills, and concrete teaching tool support.

In the context of South Papua, the challenges of implementing STEM-PBL also need to be understood through the geographical conditions of the vast Merauke area, with uneven access between schools, training, learning resources, and digital infrastructure. Geographical conditions like this can limit teachers' opportunities to participate in training, collaborate with fellow physics teachers, and obtain examples of STEM-PBL teaching tools that are appropriate to the local context. Therefore, teachers' difficulties are not only a matter of individual ability, but also related to the limitations of the ecosystem to support innovative learning in specific geographical areas. Studies on education in the Papua region also show that geographical remoteness, limited infrastructure, and lack of educational resources can affect access to quality learning (Butarbutar, 2025).

In the context of this study, the findings confirm that physics teachers in Merauke Regency already have an initial basis to implement innovative learning, but still need more systematic and contextual teaching tools. Therefore, the development of STEM-PBL e-modules that integrate Papuan local wisdom is relevant as a solution to help teachers implement more directed, contextual, and oriented learning to improve students' critical thinking skills and creativity (Putri & Turaqulov, 2022; Fitri & Asrizal, 2023).

Learning Activities

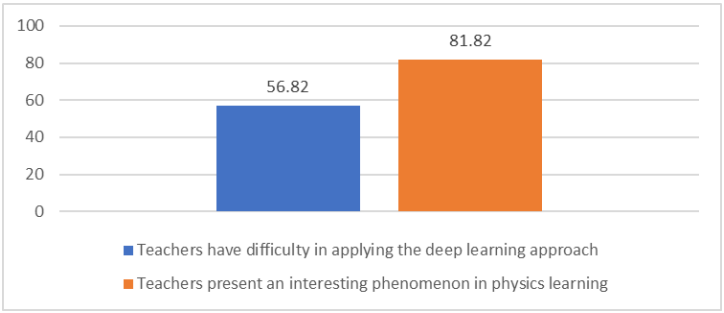

Figure 4. Learning Activist Graph

The figure 4 show that 56.82% of teachers still had difficulties in implementing the deep learning approach, while 81.82% of teachers had presented an interesting phenomenon in physics learning. These findings show a positive trend that teachers have tried to build contextual learning and spark students' curiosity through physics phenomena. Presenting interesting phenomena is an important first step in learning physics because it can activate attention, connect concepts with real experiences, and encourage students' cognitive engagement.

However, the high percentage of teachers who still have difficulty implementing deep learning indicates that learning has not fully moved from the stimulation stage to deep, reflective, and meaningful learning. Theoretically, deep learning not only requires students to observe phenomena, but also to analyze, connect concepts, solve problems, and generate new ideas. In this context, the presentation of phenomena without the support of pedagogical strategies and structured teaching materials risks stopping at the level of surface learning.

The qualitative data from the interviews reinforce the quantitative findings. One of the teachers stated: *"I try to show interesting physics phenomena, like sound waves from local musical instruments, but it is hard to guide students to analyze and connect these to physics concepts systematically."*

This quote confirms the gap between teachers' interest in presenting interesting phenomena and pedagogical ability to develop deep learning. Triangulation analysis shows that these constraints are related to the limitations of structured teaching materials, few local references, and lack of teacher training in STEM-PBL-based deep learning strategies. This phenomenon is in line with previous research that shows that STEM and PBL are more effective when supported by teaching tools that direct students from observation of phenomena to investigation, reasoning, and solution design (Albus et al., 2021).

These findings are in line with research that confirms that problem-based and STEM learning is more effective when supported by teaching tools that are able to

direct students from the observation of phenomena to investigation, reasoning, and solution design (Naurah Nazifah, 2024; Liu, 2025). Other studies have also shown that STEM and PBL-based physics e-modules can help teachers deliver more systematic, interactive, and critical thinking and creativity-oriented learning (Rahmawati et al., 2021; Fitri & Asrizal, 2023).

In the context of this study, the results confirm that physics teachers in Merauke Regency already have good initial capital in building contextual learning through interesting phenomena, but still need the support of teaching tools to realize in-depth learning consistently. Therefore, the development of STEM-PBL e-modules that integrate local Papuan wisdom is important so that local phenomena that are close to students' lives do not only function as a sparker. But it also serves as a basis for building analysis, critical thinking, and creativity in sound wave learning.

Learning Materials

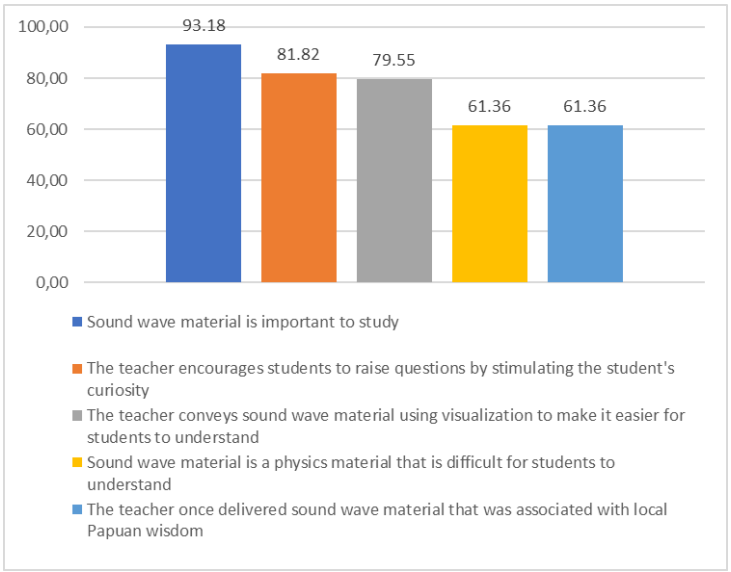

Figure 5. Learning Material Graph

Based on the figure 5, 93.18% of teachers stated that sound wave material is important to learn. These findings suggest that the topic of sound waves is seen as an essential material in physics learning because it is close to everyday phenomena and relevant to be developed through contextual learning. In addition, 81.82% of teachers encouraged students to raise questions and 79.55% of teachers delivered material using visualizations to make it easier to understand. This data shows that most teachers have made efforts to implement learning that sparks curiosity and helps students understand abstract concepts through visual representations. This is in line with the constructivist view that science learning will be more effective when students actively ask questions, observe phenomena, and build knowledge through meaningful learning

experiences. Previous research has also shown that STEM-based physics e-modules can support concept understanding while increasing students' critical thinking and creativity (Rahmawati et al., 2021; Naurah Nazifah, 2024).

On the other hand, 61.36% of teachers stated that sound wave material is still difficult for students to understand, and the same percentage, namely 61.36%, stated that they have associated sound wave material with local Papuan wisdom. These findings point to two important things. First, the abstract character of sound wave material is still a real challenge in learning. Second, the integration of Papuan local wisdom has begun to be carried out, but it is not yet fully strong and systematic. In fact, previous studies have confirmed that integrating indigenous knowledge in STEM learning can increase the relevance of the material, student involvement, and the proximity of science concepts to students' cultural experiences (Kamila et al., 2024; Matindike & Ramdhany, 2025).

The interview data supports the importance of STEM-PBL-based e-modules and local wisdom. One of the teachers said: *"I want a structured e-module that integrates Papuan local wisdom with sound wave topics, so students can not only observe phenomena but also analyze and apply the concepts creatively."*

These findings point to a gap between current teacher practices and the need for local context-based deep learning. In this context, the use of visualization and triggering questions is not enough if it is not supported by structured, interactive, and contextual teaching materials. Research on local wisdom-based STEM modules on sound wave materials shows that this kind of approach is feasible and effective for enhancing students' learning creativity (Putri & Turaqulov, 2022). Other research also confirms that STEM-based sound and light wave e-modules are valid to support critical and creative thinking skills (Fathiya & Asrizal, 2022).

Overall, these results confirm that physics teachers in Merauke Regency have a positive perception of the importance of sound wave material and have made efforts to build active learning through questions and visualization. However, there are still obstacles in the level of student understanding and the relationship of the material with local Papuan wisdom has not been optimal. Therefore, the development of STEM-PBL e-modules that integrate local Papuan wisdom is important to provide sound wave learning that is more contextual, easy to understand, and has the potential to improve students' critical thinking skills and creativity.

Critical Thinking Skills

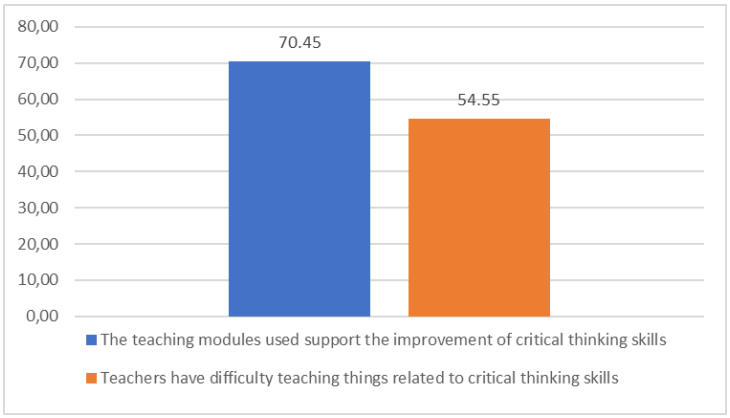

Figure 6. Critical Thinking Skills

Based on the figure 6, 70.45% of teachers stated that the teaching modules used have supported the improvement of critical thinking skills, while 54.55% of teachers still have difficulty teaching aspects related to critical thinking skills. These findings show that in general, teachers have viewed teaching modules as a potential means to practice critical thinking, but their implementation in the classroom has not been entirely easy.

A fairly high percentage of teaching module support indicates that teaching materials have an important role in directing students to higher-level thinking activities, especially when the material is presented in a contextual, problematic, and exploration-based manner. This is in line with the findings that STEM-based physics e-modules can improve students' critical thinking skills and creativity because they combine concept understanding, visualization, and active learning activities (Naurah Nazifah, 2024). The study of the needs of Hybrid-PBL-based physics e-modules also confirms that teachers need digital teaching materials that are able to present contextual problems, images, videos, and simulations to support students' reasoning (Rahmawati et al., 2021).

However, the fact that 54.55% of teachers still have difficulty teaching critical thinking skills shows that the development of critical thinking is not enough to rely only on the existence of modules, but also requires the right learning strategy. Theoretically, critical thinking develops when students are faced with authentic problems, asked to analyze evidence, formulate arguments, and evaluate solutions. Therefore, PBL-based and STEM-based learning is relevant, as they provide space for students to conduct in-depth investigation and reasoning (Hudha et al., 2023; Liu, 2025).

Qualitative data adds to the understanding of this phenomenon. One of the teachers stated: *"I try to encourage students to analyze sound wave experiments, but they often struggle to connect the results to the theory or to question the outcomes critically."*

This quote emphasizes that although modules are available, students' critical thinking skills do not automatically develop without proper teaching strategies. Triangulation analysis reveals the relationship between module content, contextual experience, and teachers' pedagogical skills: teachers who are more pedagogically prepared tend to be able to facilitate students' analysis and reflection more effectively. On the other hand, pedagogical limitations, such as the experience of relating authentic problems to local contexts, limit the effectiveness of modules in developing critical thinking.

In the context of this study, the findings confirm that physics teachers in Merauke Regency need a more structured and contextual STEM-PBL e-module, especially one that integrates local Papuan wisdom. The integration of local contexts is important because it can bring physics problems closer to the student's experience, thus facilitating the process of analysis and reflection. Previous studies have shown that the integration of indigenous knowledge in STEM learning can increase the relevance of the material and support the development of 21st century skills (Kamila et al., 2024; Matindike & Ramdhany, 2025)

Thus, these results show that the teaching module is perceived to be enough to support the development of critical thinking, but teachers still face pedagogical obstacles in teaching it. Therefore, the development of STEM-PBL e-modules based on Papuan local wisdom is important so that sound wave learning is more contextual, systematic, and effective in improving students' critical thinking skills.

Creativity

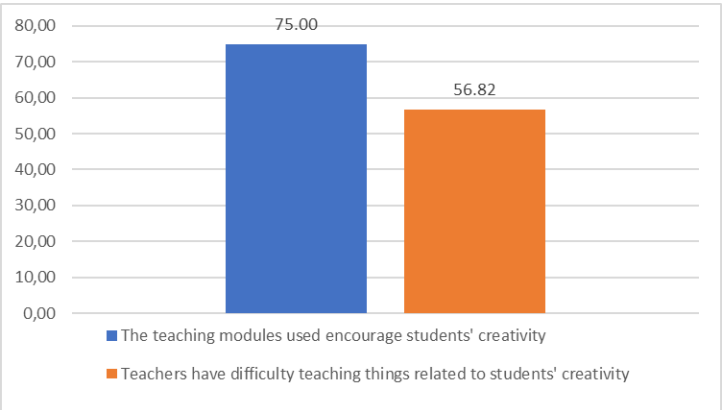

Figure 7. Creativity Graph

Based on the figure 7, 75.00% of teachers stated that the teaching modules used have encouraged students' creativity, while 56.82% of teachers still have difficulty teaching aspects related to student creativity. These findings show that teaching modules are perceived to have enough potential to stimulate creativity, but the implementation of learning that truly develops creativity is not entirely easy for teachers to do.

A fairly high percentage of teaching module support for creativity indicates that teaching materials play an important role in presenting open, contextual, and challenging learning activities. Within the framework of constructivist theory, creativity grows when students are given space to explore ideas, solve problems, and come up with diverse solutions. Therefore, teaching modules designed based on STEM and authentic problems have great potential in fostering creativity. These findings are in line with research showing that STEM-based physics e-modules have a positive impact on students' creative thinking skills (Nazifah, 2024).

However, the fact that there are still 56.82% of teachers who have difficulty teaching creativity shows that the development of creativity does not only depend on the availability of modules, but also requires the right pedagogical strategy. Creativity in physics learning requires teachers to design open-ended problems, exploratory experiments, visualizations, and activities that give students the opportunity to come up with original ideas. Previous studies have confirmed that the integration of STEM-PBL and local contexts is more effective in building creativity because students not only understand concepts, but are also involved in the process of designing, testing, and reflecting solutions to real-world problems (Sumarni et al., 2021; Pratiwi et al., 2025).

Qualitative data provides important context. One of the teachers stated: *"I try to give students open-ended problems related to sound waves, but many still hesitate to suggest their own ideas because they are not used to exploring beyond the examples in the module."*

This excerpt shows that although the module provides material that enables creativity, students still need pedagogical guidance to actively participate. The triangulation analysis revealed the relationship between module availability, teacher pedagogical readiness, and student involvement in creative activities. Teachers who are able to facilitate the exploration of open ideas report an increase in students' ability to design, test, and modify solutions to physics problems, while pedagogical limitations limit the effectiveness of modules.

In the context of this study, the results confirm that physics teachers in Merauke Regency need teaching materials that are not only informative, but also designed to facilitate creativity systematically. The integration of Papuan local wisdom is important because it can provide a context that is close to students' lives, so that creative ideas can more easily emerge from their cultural and environmental experiences. Previous studies have shown that integrating indigenous knowledge in

STEM learning can increase the relevance of learning and support the development of 21st century skills, including creativity (Kamila et al., 2024; Matindike & Ramdhany, 2025)

Thus, these results show that the teaching module has been perceived to be enough to support the development of students' creativity, but teachers still face obstacles in teaching it optimally. Therefore, the development of STEM-PBL e-modules based on Papuan local wisdom is important so that sound wave learning is more contextual, interactive, and effective in fostering student creativity.

D. Conclusion

The need for physics teachers in Merauke Regency for STEM-PBL-based e-modules that integrate local Papuan wisdom is categorized as high, shown by 81.82% of teachers interested in developing modules containing local wisdom, 84.09% have used experimental methods, and 75.00% have implemented PBL. However, there is a gap between interest and implementation capacity, where 63.64% of teachers have difficulty developing modules with local wisdom, only 52.27% apply STEM-PBL in an integrated manner, and the integration of local wisdom is still partial even though 93.18% of teachers consider sound wave material as an essential topic.

These findings imply that the development of STEM-PBL e-modules based on Papuan local wisdom is an urgent need and a strategic solution to bridge the gap between teachers' learning practices and the demands of 21st century learning. The e-modules developed need to contain explicit STEM-PBL syntax, authentic Papuan culture-based phenomena, interactive visualizations, and concrete pedagogical guidance. This study has limitations on the limited number of samples (11 teachers) so that the findings cannot be generalized, as well as limited coverage at the Analyze stage within the ADDIE framework, so further studies in the form of development and effectiveness tests of e-modules with larger samples are highly recommended.

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