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# Analysis of Teacher Needs for Science E-Book Teaching Materials Using the PBL Model with an In-Depth Learning Approach in Junior High Schools

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**ABSTRACT**

This study aims to analyze Science teachers' needs regarding the development of a digital learning resource in the form of an e-book based on the Problem-Based Learning (PBL) model to support deep learning in junior high schools. Using a descriptive qualitative design, data were collected from 30 Science teachers in Meranti Islands Regency through an online questionnaire and interviews. The findings reveal that Science learning is still dominated by conventional printed textbooks, resulting in limited student engagement and challenges in understanding abstract concepts. Teachers identified several barriers to the use of digital learning materials, including limited ICT competence, insufficient technological facilities, and time constraints. Despite these challenges, the study indicates a strong demand for e-books with multimedia features, interactive components, structured project guidance, and collaborative learning support. Teachers believe that a PBL-based e-book has the potential to improve students' concept mastery, critical thinking, and problem-solving skills by enabling self-paced learning and providing opportunities for inquiry and collaboration. These results underscore the importance of developing a PBL-oriented Science e-book as an innovative solution to align instructional practices with the Merdeka Curriculum and digital learning transformation.

**Keywords:** PBL-based e-book, deep learning, science learning

## INTRODUCTION

The rapid progress of digital technology has significantly influenced educational practices, particularly at the junior high school level. One notable transformation is the shift from conventional printed learning materials toward digital learning resources such as e-books. E-books provide advantages in accessibility, interactivity, flexibility, and the ability to update learning content in real time, offering new possibilities for improving science learning outcomes [1]. In this context, the present study seeks to investigate teachers' needs regarding the development of an e-book for Science (IPA) that integrates a Problem-Based Learning (PBL) model with a deep learning approach to enhance learning effectiveness in secondary schools.

The issue of low academic performance in Science at Indonesian junior high schools remains a multidimensional challenge. Research has highlighted difficulties in implementing the Merdeka Curriculum, which emphasizes meaningful learning outcomes and student-centered instruction [2], [3], [4]. Although the curriculum offers flexibility through innovative teaching methods, many teachers are still struggling to design and conduct learning aligned with such expectations. These limitations raise the need for practical teaching resources capable of supporting the curriculum's vision and improving the quality of Science learning nationwide.

Project-Based Learning (PBL) emerges as a pedagogical model capable of actualizing the goals of the Merdeka Curriculum by exposing students to authentic phenomena and encouraging meaningful engagement in the learning process. PBL stimulates the development of scientific concepts, collaboration, communication, and creativity—skills urgently required in the twenty-first century [5], [6], [7]. However, PBL implementation in many schools remains suboptimal due to teachers' limited understanding of the model and insufficient availability of supporting resources [8]. Therefore, providing structured and accessible learning materials aligned with the PBL model is essential.

The need for digital learning materials becomes even more apparent with the expansion of technological integration in Indonesian schools. According to the Ministry of Education and Culture, more than 70% of schools have incorporated information and communication technology in learning activities. Despite this growth, many instructional materials remain conventional and do not yet support differentiated learning. Agusningtyas et al., found that teachers urgently require interactive e-modules that provide flexibility in content, process, and product adaptation to accommodate student diversity [9]. While previous studies have developed various digital resources—including interactive e-modules [10], [11], digital booklets [12], and subject-specific applications such as SIMEZA [13], [14]—these existing materials predominantly focus on content delivery rather than systematically integrating pedagogical frameworks that promote deep learning. Furthermore, none of these studies specifically address the unique challenges of Science instruction in remote regions such as Meranti Islands Regency, where technological infrastructure and teacher readiness present distinct barriers to digital learning implementation.

Moreover, the shift toward deep and meaningful learning emphasizes the necessity of instructional practices that develop higher-order thinking skills (HOTS). The prevalence of surface learning—characterized by rote memorization, passive learning, and limited conceptual depth—has inhibited students' ability to think analytically and creatively in Science [15]. To address this issue, adopting instructional models that foster critical thinking, problem solving, and reflective inquiry is crucial. The literature strongly supports the effectiveness of PBL in enhancing these competencies by engaging students with real-world problems and encouraging collaborative reasoning [16], [17], [18], [19]. However, existing PBL implementations in Indonesian schools remain largely unsupported by structured digital resources that scaffold the entire inquiry process, leaving teachers to design project materials independently without adequate guidance or technological integration [20], [21], [22].

This study addresses these gaps by proposing an innovative integration of Problem-Based Learning (PBL) within an interactive e-book format specifically designed to support deep learning in Science education. Unlike conventional digital materials that merely digitize static content, the proposed PBL-based e-book systematically embeds real-world problem scenarios, structured project workflows, multimedia simulations, virtual laboratory activities, and authentic assessments—creating a comprehensive learning ecosystem that scaffolds both cognitive processes and collaborative inquiry. Furthermore, this research specifically investigates teacher needs in Meranti Islands Regency, a context characterized by limited digital infrastructure and emerging technological adoption, thereby contributing contextualized insights that extend beyond urban-centric educational research. By examining how PBL principles can be operationalized within accessible digital formats tailored to local constraints, this study offers a novel pedagogical-technological framework that bridges the gap between curriculum mandates for deep learning and practical classroom implementation in resource-limited settings.

Based on these empirical and contextual considerations, identifying teachers' needs regarding an e-book for Science that integrates PBL and a deep learning approach becomes vital. A needs analysis is required to ensure that the developed material aligns with pedagogical expectations, curricular demands, and technological readiness in schools. Therefore, this study aims to map and understand teachers' perspectives, challenges, and expectations related to the design and use of a PBL-based Science e-book to support meaningful learning in junior high schools. The findings are expected to provide strong groundwork for the development of innovative digital learning resources and for future efforts to enhance professional development in technology-supported learning.

## RESEARCH METHODS

This study employed a descriptive qualitative research design to explore teachers' needs regarding the development of a PBL-based Science (IPA) e-book that supports deep learning in junior high schools. Thirty Science teachers from several public and private junior high schools in Meranti Islands Regency were selected as research participants through purposive sampling. The selection criteria included holding a certified teaching credential, having a minimum of five years of teaching experience, and expressing willingness to participate in the study. This sampling strategy was chosen to ensure that participants possessed sufficient pedagogical and technological experience to provide meaningful insights into the implementation of PBL, deep learning, and digital learning materials such as e-books.

Data were collected using an online questionnaire distributed via Google Form. The instrument consisted of a series of open-ended questions designed to elicit teachers' perceptions and expectations related to the use of e-books in Science instruction, including their needs for learning content, obstacles in implementing PBL and deep learning, and preferred digital features that would support interactive and differentiated learning. The qualitative data obtained from teachers' responses were subsequently analyzed through thematic analysis to identify emerging patterns and categorize instructional needs in relation to curriculum demands, PBL components, and the deep learning approach. This methodological approach allowed the study to comprehensively describe teachers' perspectives as a basis for the future development of a digital Science learning resource aligned with pedagogical and technological advancements.

## RESULT AND DISCUSSION

### 1. Profile of Conventional Teaching Material Usage in Science Learning

a. Dominance of Printed Textbooks as Primary Learning Resources

The research findings demonstrate that Science learning in junior high schools of Meranti Islands Regency remains predominantly dependent on conventional teaching materials, specifically printed textbooks. Data obtained from 30 teacher respondents revealed that 22 teachers (73.3%) identified textbooks as their primary instructional resource. This finding indicates a remarkably high reliance on printed materials among Science teachers, despite the rapid advancement of digital technologies in recent years. The dominance of textbook usage reflects prevailing infrastructural limitations and well-established pedagogical habits embedded in daily teaching practices.

Beyond textbooks, several teachers reported using teaching modules (3 respondents, 10%), student worksheets (3 respondents, 10%), and posters (1 respondent, 3.3%). Only a single teacher (3.3%) reported utilizing e-books as instructional materials for Science learning. This extremely low proportion of digital material adoption serves as a critical indicator that educational digital transformation has not yet achieved equitable distribution, particularly in geographically constrained regions such as Meranti Islands. This condition differs significantly from some previous studies, who reported that junior high school Science teachers in urban areas had begun adopting interactive instructional materials [23], [24]. The complete distribution of teaching material usage is presented in Table 1 below:

**Table 1.** Distribution of Teaching Material Usage in Science Learning

| Type of Teaching Material | Number of Teachers | Percentage (%) |
|---|---|---|
| Textbooks | 22 | 73.3 |
| Teaching Modules | 3 | 10.0 |
| Student Worksheets (LKS) | 3 | 10.0 |
| E-books | 1 | 3.3 |
| Posters/Others | 1 | 3.3 |
| Total | 30 | 100.0 |

As illustrated in Table 1, textbooks clearly dominate instructional material usage with a substantial percentage of 73.3%. This dominance carries significant implications for Science learning quality, considering that conventional textbooks generally possess inherent limitations in presenting abstract concepts requiring dynamic visualization. These findings align with some previous studies, who discovered that dependence on printed textbooks contributes to reduced student engagement in active learning [25], [26], [27], [28]. Furthermore, some previous studies emphasize that conventional teaching materials tend to inadequately support differentiated learning, which constitutes a fundamental requirement of the Merdeka Curriculum [29], [30].

b. Impact of Conventional Material Usage on Learning Quality

The predominant use of conventional teaching materials directly affects the quality of Science learning processes and outcomes in the field. In-depth interview results with 8 teacher informants revealed that printed textbooks frequently create constraints on student engagement during learning activities. Teachers reported that students tend to exhibit passive behavior when instruction relies solely on teacher explanations supported by static images or diagrams from textbooks. This condition becomes increasingly problematic when addressing abstract concepts such as ecosystems, organism-environment interactions, and physical-chemical changes that cannot be directly observed in everyday life.

Classroom observations conducted by the researcher confirmed these interview findings. Student activities during Science learning were identified as teacher-centered, with limited interaction between students and instructional materials. Students rarely utilized digital devices during learning activities, even in schools equipped with computers and projectors. This finding suggests that technological infrastructure availability does not proportionally correlate with its pedagogical utilization. These results correspond with the arguments of Ndari et al., and Rahman et al., who state that Merdeka Curriculum implementation faces fundamental challenges arising from teacher unpreparedness in transforming learning paradigms from conventional approaches toward more student-centered methodologies [31], [32].

The research also uncovered that textbook dependence creates learning patterns emphasizing rote memorization rather than deep conceptual understanding. Responding teachers acknowledged that students tend to memorize definitions and formulas without comprehending their meanings and real-world applications. This condition represents a manifestation of surface learning extensively documented in Science education literature. Sucipto and Jiwandono affirm that memorization-based learning hinders the development of Higher Order Thinking Skills (HOTS), which constitute essential competencies in the 21st century [33], [34]. Consequently, these findings underscore the urgent necessity for developing innovative teaching materials capable of accelerating Science learning transformation toward more meaningful and profound approaches.

2. **Barriers to Digital-Based Teaching Material Implementation**

a. Infrastructure and Technological Facility Limitations

This study identified various barriers faced by teachers in implementing digital-based teaching materials for Science instruction.

Questionnaire data indicated that facility limitations represent the primary barrier, reported by 11 teachers (36.7%). These limitations encompass inadequate availability of computers, laptops, Chromebooks, and other supporting infrastructure in most schools. In several schools located on remote islands, unstable or completely unavailable internet access presents an additional significant obstacle for technology-assisted learning implementation.

These facility constraints cannot be separated from the geographical context of Meranti Islands Regency, which comprises dozens of large and small islands. Some schools are situated on islands accessible only by boat requiring several hours of travel, rendering technology device distribution and maintenance complex logistical challenges. These findings are consistent with the research of Song et al., who developed the Mobile-Assisted Personalized Learning (MAPL) model specifically to address digital divide issues in developing regions with limited infrastructure [35]. Their model emphasizes the importance of developing digital teaching materials accessible via mobile devices and low bandwidth, recognizing student dependence on mobile technology as primary learning tools. The detailed distribution of barriers to digital material usage is presented in Table 2 below:

**Table 2.** Distribution of Barriers to Digital Teaching Material Usage

| Type of Barrier | Number of Teachers | Percentage (%) |
|---|---|---|
| Facility/technology limitations | 11 | 36.7 |
| Low ICT skills | 10 | 33.3 |
| Time constraints | 7 | 23.3 |
| Other barriers | 2 | 6.7 |
| **Total** | **30** | **100.0** |

As presented in Table 2, facility/technology limitations rank first as the primary barrier, followed by low ICT skills (33.3%) and time constraints (23.3%). The nearly balanced proportion between facility limitations and ICT skills indicates that these factors are interrelated and require comprehensive interventions. The research of Ng and Fergusson within the Technology-Enhanced Science Partnership Initiative demonstrates that effective Science teacher development programs must simultaneously integrate technological and pedagogical aspects, rather than treating them as separate initiatives [36]. These findings are relevant to the present research context, which indicates the necessity of developing teacher capacities in both technical and digital pedagogy dimensions.

b. Teacher Digital Competency and Time Limitations

Beyond infrastructure constraints, teacher digital competency constitutes the second significant barrier, reported by 10 teachers (33.3%). In-depth interview results revealed that numerous teachers lack confidence in independently operating digital platforms. Several teachers admitted experiencing technology anxiety that hinders exploration and adoption of digital teaching materials, despite available devices and platforms at their schools. This condition indicates that technology availability alone proves insufficient without accompanying enhancement of comprehensive Technological Pedagogical Content Knowledge (TPACK).

Responding teachers consistently expressed needs for training supporting digital pedagogy development and reducing technology-related anxiety. They indicated willingness to participate in professional development programs focused on practical and applicable digital teaching material utilization. These findings align with the research of Nurfadilah et al., and Rafiudin et al., who demonstrate the effectiveness of real life-based digital teaching material training in enhancing teacher capacities [37], [38]. Such training develops not only technical skills but also builds teacher confidence in integrating technology into daily pedagogical practices.

Time constraints emerged as the third barrier, reported by 7 teachers (23.3%). Teachers stated that dense teaching schedules and heavy administrative burdens make designing or integrating digital materials into lesson plans difficult. Field observations confirmed that teachers frequently prioritize curriculum coverage over exploring new learning strategies due to time limitations. The combination of limited digital competency, inadequate infrastructure, and restricted time creates a learning environment unprepared for digital transformation. This corresponds with the findings of Hanum & Dalimunte, who identify that successful Merdeka Curriculum implementation depends critically on sustained support through training, mentoring, and adequate resource availability [39].

**3. Teacher Needs for Innovative Digital Teaching Materials**

a. Preferences for Multimedia Features and Visual Design

Despite facing various barriers, the research findings reveal strong teacher demand for innovative Science teaching materials supporting active student engagement. Questionnaire data uncovered that multimedia features comprising animation, images, and video represent the most requested characteristics, identified by 10 teachers (33.3%). This preference reflects teacher awareness of dynamic visualization importance in helping students comprehend abstract Science concepts. Teachers believe that Science concepts become more comprehensible when accompanied by simulations, moving illustrations, and animated explanations.

Attractive design ranked second, with 6 teachers (20.0%) identifying it as an important need. Teachers emphasized that monotonous teaching materials failing to stimulate student curiosity constitute significant obstacles in current learning. They require materials with aesthetic layouts, appropriate color schemes, and design elements capable of maintaining student attention throughout learning processes. These findings are consistent with the research of Sholikhah et al., who developed 3D virtual fashion design e-modules using CLO3D software, where visual and interactive aspects proved effective in enhancing student engagement and 21st-century skill development [40]. The complete distribution of required teaching material characteristics is presented in Table 3 below:

**Table 3.** Required Characteristics of Teaching Materials

| Characteristic of Teaching Material | Number of Teachers | Percentage (%) |
|---|---|---|
| Animation, images, and video | 10 | 33.3 |
| Attractive design | 6 | 20.0 |
| Interactive features | 6 | 20.0 |
| Collaboration support | 5 | 16.7 |
| Curriculum relevance | 3 | 10.0 |
| **Total** | **30** | **100.0** |

As illustrated in Table 3, multimedia and visual aspects dominate teacher needs, totaling 53.3% for animation/images/video and attractive design combined. This indicates teacher awareness of printed textbook limitations in presenting material visually and dynamically. The research of Indriani et al., in developing HTML5-assisted digital booklets demonstrates that good visual design significantly contributes to improved student motivation and comprehension of learning material [41]. Similarly, Azkia et al., in developing the SIMEZA application for Islamic education learning found that interactive multimedia elements effectively assist sixth-grade student comprehension of abstract concepts [13].

b. Needs for Interactivity and Collaborative Support

Interactive features emerged as the third important need, reported by 6 teachers (20.0%). Teachers expect materials enabling students to directly interact with content, receive instant feedback, and control learning pace according to individual abilities. This interactivity feature is considered crucial for supporting differentiated learning, where students with varying abilities can access and comprehend material according to their respective needs. These findings are relevant to the research of Agusningtyas et al., who reported that 81% of teachers require interactive media to assist learning, and 83% of teachers are prepared to use interactive media to help students overcome learning difficulties [9].

Support for collaborative learning emerged as the fourth need, identified by 5 teachers (16.7%). Teachers conveyed that Science learning proves more successful when students communicate and share responsibility throughout inquiry processes. They require materials facilitating group discussion, project collaboration, and learning outcome sharing. Several teachers added that current teaching materials feel monotonous and fail to stimulate student curiosity for discussion and cooperation. These findings align with the research of Al-Thani & Ahmad, who emphasize technology's important role in facilitating innovative, hands-on research experiences within Project-Based Learning and Problem-Based Learning frameworks [42].

Additional document analysis revealed that teachers still manually design project worksheets and assessment instruments because no digital teaching resources are specifically designed to support project-based learning. Teachers expressed hope for materials systematically guiding project implementation, offering structured scenarios, guiding questions, and authentic assessments. These results emphasize the necessity for interactive, visually appealing, practical, and curriculum-aligned Science e-books. Eswaran in examining Project-Based Learning affirms that effective teaching materials must scaffold the entire inquiry process, not merely provide factual information, enabling students to simultaneously develop collaboration, creativity, and critical thinking [43].

### 4. Potential of PBL-Based E-Books for Supporting Deep Learning

a. Teacher Perceptions of Multimedia Benefits for Conceptual Understanding

The research findings captured teacher perceptions regarding how PBL-based e-books could benefit Science learning. Teachers generally expressed optimism that multimedia content integration would make Science concepts more comprehensible and engaging for students. Video and animation were perceived as crucial features because they can demonstrate abstract processes difficult to observe directly in classrooms, such as particle movement in substances, microscopic chemical reactions, or ecosystem interactions occurring over extended time scales.

Teachers believed that multimedia representations could support conceptual comprehension by visualizing phenomena impossible to observe directly—an essential aspect of deep learning. This perception aligns with multimedia learning principles articulated by some previous studies, where combining visual and verbal processing can enhance deep conceptual understanding [44], [45]. The research of Ormancı & Çepni on interactive e-book use in Turkish Science education demonstrates that both teachers and students implementing e-books hold positive views regarding their effectiveness in improving conceptual understanding and learning motivation [46].

Furthermore, teachers believed that interactive features would enable self-paced learning. Participants indicated that e-books providing navigation freedom, clickable tasks, and virtual exploration activities could help students repeat challenging content and develop deeper conceptual understanding. This aligns with deep learning principles prioritizing active learning and meaningful knowledge construction rather than memorization. Some previous studies shows that PBL model application significantly enhances student critical thinking and problem-solving abilities in physics learning, which constitute primary indicators of deep learning [47], [48].

b. Support for Self-Directed and Collaborative Learning

Another theme highlighted in interviews was the potential of PBL-based e-books to enhance student collaboration. Teachers stated that Science projects prove more successful when students communicate and share responsibility throughout inquiry processes. They expected that e-books equipped with discussion prompts, digital worksheets, and project rubrics would improve student collaboration and problem-solving. These expectations confirm that teachers view PBL-based Science e-book development as highly relevant for supporting Science learning in the digital era.

The relationship between PBL, collaboration, and deep learning has been extensively documented in educational literature. Some previous studies found that the PBL model significantly affects student critical thinking abilities through collaborative activities in solving authentic problems [49], [50]. Similarly, some previous studies reported that PBL model application successfully developed elementary students' Higher Order Thinking Skills through structured inquiry processes [51], [52]. Widiastuti et al., affirm that PBL constitutes an effective learning model for developing student critical thinking by involving them in authentic problem-solving [53].

This research's specific contribution lies in identifying the need for e-books functioning not merely as content repositories but as learning ecosystems actively facilitating interaction, inquiry, and peer learning. These findings reinforce the view that developing PBL-based Science e-books represents not simply a technological innovation but a necessity for aligning pedagogical practices with curriculum demands, digital transformation, and higher-order thinking skill development. As expressed by Putu & Wijaya and Novitasary, project-based learning implementation within the Merdeka Curriculum requires structured and accessible resources enabling effective teacher implementation without excessive workload burdens [5], [7].

**5. Discussion of Findings within Policy and Educational Practice Contexts**

a. Gap Between Curriculum Demands and Learning Realities

These research findings highlight a persistent gap between Merdeka Curriculum demands and actual field learning practices. The Merdeka Curriculum emphasizes meaningful learning, student-centered approaches, and Pancasila Student Profile development encompassing critical, creative, and independent thinking. However, high dependence on printed textbooks and limited availability of teaching materials supporting such approaches create misalignment between curriculum vision and actual student learning experiences.

This gap is not unique to Meranti Islands Regency but reflects national challenges in Merdeka Curriculum implementation. Kartika in unveiling the Merdeka Curriculum in Indonesia found that curriculum implementation success depends on aspects including Pancasila values internalization, contextual learning, student mindset changes, parental involvement, character strengthening focus, and active learning [54]. However, these findings also indicate that achieving these aspects requires adequate learning resources and systematic teacher support. The present research findings confirm that current resource inadequacy constitutes one critical factor hindering curriculum goal realization.

b. Implications for Teaching Material Development and Teacher Professional Development

These research findings carry significant implications for educational policy development and practice at regional and national levels. First, the strong demand for digital teaching materials with multimedia, interactivity, and collaborative support features indicates priority directions for learning resource development. The proposed PBL-based e-book development offers a comprehensive solution integrating pedagogical needs (deep learning, HOTS, collaboration) with technological needs (multimedia, interactivity, accessibility).

Second, the identification of teacher ICT competency limitations underscores the urgency of sustained professional development programs. Effective training must not be limited to technical software operation aspects but must encompass technology pedagogy integrating TPACK. Prayunisa et al., demonstrate that TPACK-based scientific approaches positively affect Merdeka Curriculum implementation and junior high school Science learning outcomes [2]. These findings provide empirical grounds that investment in teacher TPACK capacity development will yield significant returns in learning quality improvement.

Third, Meranti Islands' unique geographical context demands teaching material development approaches sensitive to infrastructure limitations. Proposed solutions must consider low-bandwidth accessibility, mobile device compatibility, and offline access possibilities. The MAPL model developed by Song et al., can serve as a reference for designing e-books flexibly accessible despite internet connectivity limitations [35]. Such approaches are crucial for ensuring equitable access to quality learning resources and reducing digital divides between regions.

c. Theoretical and Practical Contributions of the Research

Theoretically, this research contributes to understanding mechanisms connecting teaching material characteristics, pedagogical approaches (PBL), and learning depth (deep learning) within Indonesian Science education contexts. The identification of teacher needs for e-books functioning as learning ecosystems—rather than mere content repositories—enriches technology-based learning design literature. This concept aligns with recent developments in educational technology emphasizing integrated learning ecosystems rather than fragmented resources.

Practically, these research findings provide empirical foundations for teaching material developers, policymakers, and educational practitioners in designing locally responsive solutions. The comprehensive mapping of teacher needs—including feature preferences, implementation barriers, and pedagogical expectations—yields clear technical and pedagogical specifications for PBL-based e-book development. Furthermore, this research identifies that teaching material development must be accompanied by implementation strategies accounting for teacher time constraints, thereby reducing rather than increasing workload.

The findings regarding PBL-based e-book potential for enhancing collaboration and communication also prove relevant to 21st-century competency development, which constitutes Merdeka Curriculum focus. Gumanti et al., in developing PBL-based mathematics teaching modules found significant improvement in student mathematical problem-solving capabilities [6]. Similar findings across various disciplines indicate that structured PBL approaches in digital formats possess transferable potential for enhancing various student competencies, including Science learning.

**Limitations and Recommendations for Future Research**

Despite significant contributions, this research acknowledges several limitations. First, the research sample is limited to 30 teachers in Meranti Islands Regency, requiring cautious generalization to broader contexts. Second, this research focuses on needs analysis without proceeding to product development and implementation stages, meaning the effectiveness of proposed PBL-based e-books remains empirically untested.

For future research, the following recommendations are proposed: (1) develop PBL-based e-book prototypes according to identified need specifications; (2) conduct implementation trials to measure effectiveness in enhancing student deep learning and HOTS; (3) expand sample coverage to regions with different infrastructure characteristics to enrich understanding of contextual factors; and (4) conduct longitudinal studies observing changes in teacher competency and perceptions through extended experience using digital teaching materials.

## CONCLUSION

This study concludes that Science teachers in Meranti Islands Regency urgently need a PBL-based e-book with multimedia features, interactivity, and collaborative support to facilitate deep learning, despite facing barriers of limited ICT skills, inadequate technological facilities, and time constraints. The findings confirm that conventional teaching materials currently dominate Science instruction and fail to align with Merdeka Curriculum demands for student-centered, meaningful learning experiences. Therefore, developing a PBL-oriented Science e-book represents a necessary innovation to bridge the gap between curriculum expectations and classroom realities, while future implementation must be accompanied by systematic teacher professional development and infrastructure support to ensure effective digital learning transformation.

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