Dissemination of interactive digital physics modules (IDMP) to improve teachers' Scientific Inquiry Literacy (SIL) in depth learning

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Abstract
The Background of study is strengthening Scientific Inquiry Literacy to a critical urgency to equip the younger generation with logical, analytical, and evidence-based thinking skills to face complex challenges in the 21st century. The study objective examines the dissemination of the Interactive Digital Module Physics (IDMP) in improving teachers' Scientific Inquiry Literacy (SIL) in immersive learning. The of study of method Through a mixed-methods approach with 55 science teachers in Jakarta, Indonesia aged 35-55 years as participants, data were collected through the SIL pretest-posttest and implementation observations. The results showed an adoption rate of 83.3% of the IDMP, with 73.3% of teachers successfully integrating it into their lesson plans. The implementation of the Interactive Digital Module Physics (IDMP) led to a significant improvement in teachers' scientific inquiry literacy, with N-Gain scores of 25%, 23%, and 22% in designing investigations, guiding inquiry, and evaluating scientific processes, respectively. The implication of study for demonstrate the effectiveness of the IDMP in supporting immersive learning through interactive simulation features. The development of collaborative features such as discussion forums and experimental data banks is recommended to facilitate ongoing practice among teachers.

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1. Introduction

Deep learning has emerged as a critical approach in science education in the digital age, particularly in addressing material complexity and the demands of 21st-century skills (Kwangmuang et al., 2021; West, 2023). This approach emphasizes holistic conceptual understanding, higher-order thinking, and the application of knowledge in authentic contexts. However, its implementation in Indonesia remains hindered by conventional, mechanistic teaching methods and low student engagement (Hsu et al., 2023; Solikhah, 2023). The primary challenge lies in teacher readiness not only in content mastery but also in designing inquiry-based learning experiences, problem-solving tasks, and critical reflection (Revina et al., 2023).

Advances in digital technology offer transformative opportunities through interactive media such as digital modules and virtual simulations, which can deepen conceptual understanding and scientific investigation skills (Nsabayezu et al., 2025; Wang et al., 2024). However, this potential remains underutilized due to low teacher digital literacy and a lack of effective technology integration models in lesson plans (Manalo & De Villa, 2022). Additionally, access to interactive, inquiry-based learning modules remains limited (Peltekova & Peeva, 2022).

Scientific Inquiry Literacy (SIL) is an essential competency for science teachers to design, implement, and evaluate investigation-based learning (Abdullah et al., 2022). However, studies indicate that many teachers struggle to develop SIL due to insufficient learning resources (Wahyuningsih et al., 2021; Ng et al., 2023). To address this gap, the Interactive Digital Module for Physics (IDMP) was developed, featuring interactive

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simulations and virtual labs to help teachers internalize scientific inquiry approaches (Pokhrel, 2024; Kumar & Kumar, 2025).

Orienting & Asking Questions required further reinforcement (Darman et al., 2023; Huang et al., 2025). Deeper analysis revealed that interactive feature utilization reached only 60%, and teacher collaboration in implementation was just 50%. This highlights the need for communities of practice (CoP) to facilitate idea exchange and best practices (Ali et al., 2023; Birden, 2022). IDMP not only enhances teacher competency but also has the potential to transform science education in Indonesia toward a student-centered, inquiry-based approach (Andayani et al., 2024; Rasyidi et al., 2025). The Jakarta pilot could serve as a replicable model for other regions, with adjustments for digital infrastructure and student characteristics (Permana, 2023; Bachtiar, 2025). Furthermore, curriculum shifts emphasizing differentiated learning and the Pancasila Student Profile demand teaching tools that are contextual, practical, and easily integrated (Usman et al., 2023; Dwikurnaningsih et al., 2025). Unlike traditional teacher training programs, which tend to be theoretical and one-directional (Skantz et al., 2022; Liang et al., 2023), IDMP adopts an experiential approach through simulations, interactive quizzes, and automated feedback. The module is designed to encourage independent exploration while visualizing abstract concepts via applied case studies (Fitzgerald, 2023; Huskic et al., 2022).

The era of data and technology, learning module design should be built by considering empirical data from educational practice (Shu & Gu, 2023; Almasri, 2024). The IDMP development process involves analyzing teacher needs, student learning style tendencies, and integrating features appropriate to the current digital context. By utilizing this data, the IDMP is not only responsive to changing times but also aligned with teachers' increasingly dynamic and technology-based work patterns. The success of IDMP dissemination depends heavily on the extent to which this approach is understood as a collective movement. Educational transformation cannot be achieved individually; it requires the support of a mutually reinforcing network. Dissemination is not only about disseminating products, but also about building a collaborative learning culture among teachers, across schools, and even across regions (Gupta et al., 2023; Fu & Zhang, 2024). This is where the hope of creating scientifically literate and digitally adaptive science teachers can truly be realized.

Although previous research has developed various digital modules for science learning most have focused on improving students' understanding of the content, rather than strengthening teachers' Scientific Inquiry Literacy (SIL) as agents of learning change. Previous studies have also identified limitations in Integration of Authentic Inquiry; Existing modules tend to emphasize passive simulations over independent experimental design and data analysis. There is a lack of features that facilitate communities of practice (CoP) among teachers to share implementation strategies. Contextual Fit, Existing modules lack adaptability to local curriculum needs and digital infrastructure in Indonesia. While various studies have been conducted on developing digital modules and improving teachers' scientific inquiry literacy, this study offers three key innovations: (1) the integration of deep learning concepts with interactive simulation-based inquiry approaches in a single integrated platform, a practice that has not been widely studied in the context of teacher education in Indonesia; (2) the design of the IDMP specifically developed to address the digital literacy challenges of teachers aged 35-55 through an adaptive interface and gradual scaffolding; and (3) strengthening the collaborative dimension through community of practice (CoP) features within the digital module, including discussion forums and an experimental data bank, as a sustainable strategy to improve teachers' SIL an aspect often overlooked in similar research. The combination of these three elements makes this study conceptually and practically unique in the context of science teacher professional development. Based on the background above, the objectives of this dilution research focus on (1) Implementation of the In-Depth Learning Curriculum using IDMP, especially in overcoming the limitations of learning resources and increasing learning interactivity. (2) The effectiveness of IDMP in improving teachers' SIL, including the ability to design investigations, guide inquiries, and evaluate scientific processes.

2. Method

Using a mixed-methods approach design (Creswell & Clark, 2017) with 55 science teachers in Jakarta, Indonesia aged 35-55 years as participants, data were collected through SIL pretest-posttest and implementation observations. The reason for selecting the sample is related to age because teachers in this age range generally have sufficient teaching experience (mid-career to late career). They are the most strategic group for training because they already have an established teaching pattern but are still open to capacity building, are expected to be dissemination agents for younger teachers, have a good understanding of the curriculum and student needs and the reason why the number of participants is to provide statistical power in quantitative analysis and provide diversity of school contexts and teacher characteristics. The complete stages are explained as follows: The Preparation Stage begins with the formation of a service team consisting of lecturers and students with relevant expertise. This stage includes needs analysis through surveys and interviews to identify teacher challenges related to Scientific Inquiry Literacy (SIL) and the use of IDMP (Wibowo et al., 2025). Next, the preparation of socialization and training materials tailored to teacher needs, development or selection of IDMP relevant to the physics curriculum, and logistical preparations including location, equipment, and supporting materials. The Socialization Stage focuses on introducing the program to physics teachers, covering the objectives, benefits, and implementation stages. The team provides motivation to increase IDMP adoption and opens participatory discussions to identify teacher challenges and expectations in physics learning (Wibowo et al., 2024). The intensive training phase is implemented in three aspects: strengthening the concept of inquiry learning, technical training on the use of IDMP, and strategies for integrating IDMP into learning to improve students' SIL (Wibowo et al., 2025). The training is designed interactively with concrete case studies. In the Technology Implementation Phase, teachers implement IDMP in the classroom under the guidance of the team. This phase includes trialing the use of IDMP in real-life learning, adapting modules based on student characteristics, and documenting the implementation process for evaluation. In the Mentoring Phase, the team conducts classroom observations, problem-solving discussions, and provides technical and moral support. Mentoring focuses on identifying implementation obstacles and providing real-time solutions. The Evaluation Phase is carried out through the collection of quantitative and qualitative data. Data is analyzed to measure the impact of the program, then formulated in a report containing findings, recommendations, and improvement strategies. The implementation design of the IDMP Mixed Method can be show in Figure 1.

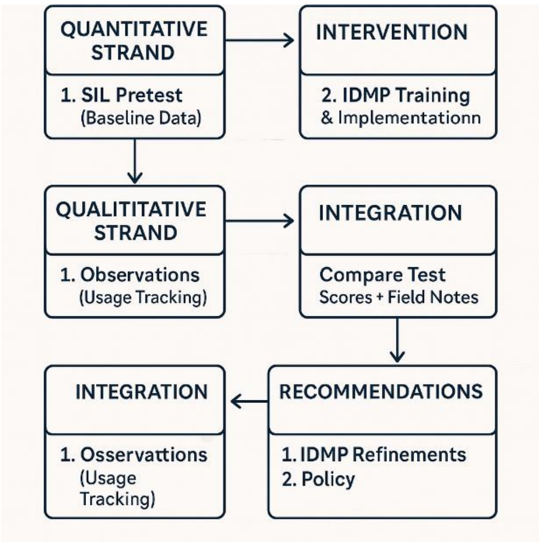

Figure 1. Desain Mixed-Methods implementasi IDMP

Besed on Figure 1 This flowchart illustrates the mixed-methods research design used to test the effectiveness of the Interactive Digital Physics Module (IDMP) in improving teachers' Scientific Inquiry Literacy (SLI). This approach combined quantitative and qualitative methods sequentially (explanatory sequential), beginning with a quantitative phase through the SIL pretest and posttest, followed by a qualitative phase involving observations of IDMP implementation in the classroom. The study participants consisted of 55 science teachers in Jakarta, Indonesia, aged 35-55, selected purposively to ensure relevance to the immersive learning context.

Data Collection and Analysis Process: Data were collected through three main instruments: (1) the SIL pretest to measure teachers' initial scientific inquiry skills, (2) a parallel SIL posttest to assess post-intervention, and (3) classroom observations to monitor IDMP implementation. Quantitative data analysis used statistical tests (paired sample t-test and N-Gain score) to measure the significance of improvements, while qualitative data were analyzed thematically to identify patterns of IDMP use and pedagogical challenges. The results of both phases were integrated through triangulation to strengthen the validity of the findings.

Methodological Implications: This mixed-methods design allows for a comprehensive understanding of the impact of the IDMP, not only in terms of SIL improvement figures but also in the context of implementation in the field. Classroom observations revealed that 73% of teachers successfully integrated the IDMP into their lesson plans, although the use of interactive features was still limited (60%). The combination of quantitative and qualitative data also identified the need to strengthen the community of practice (CoP), which was only achieved by 50%, as a recommendation for further module development.

The assessment of Scientific Literacy Skills (SLS) enhancement employs the Normalized Gain (N-Gain). This statistical tool serves as an indicator for evaluating the impact of educational interventions, specifically in measuring progress in learners' achievements. The N-Gain computation derives from the comparative analysis of pre-instructional and post-instructional assessment results, standardized against the highest attainable score. The fundamental equation for determining N-Gain is expressed as E.q 1.

$$N - Gain = \frac{Post-test\ Score - Pre-test\ Score}{Maximum\ Score - Pre-test\ Score} \quad (1)$$

Formula 1 explain about N-Gain values are classified into three categories based on the percentage of improvement: high (>70% improvement), moderate (30% improvement <70% improvement), and low (≤30% improvement), according to the standards introduced by Hake (1998). This classification is widely applied in quasi-experimental research in education to measure the effectiveness of IDMP media.

The Program Sustainability Phase concludes with the dissemination of results through seminars and publications, the establishment of a community of teachers using IDMP, and the provision of ongoing support mechanisms to ensure the initiative's sustainability. These stages can be tailored to the needs and characteristics of partners, as well as resource availability. The most important is the commitment and cooperation of all relevant parties to achieve the program's goals, namely improving the quality of physics learning and scientific inquiry literacy.

3. Results and Discussion

3.1. Implementing the Deep Learning Curriculum Using IDMP

The results of a survey of teachers participating in the community service program revealed various challenges faced in implementing the Deep Learning Curriculum in the classroom. The survey was conducted using the Mentimeter platform, where respondents were asked to identify the single biggest challenge, they experienced in implementing deep learning. The responses were visualized in word clouds, as shown in Figure 2.

Figure 2. Word Cloud of deep learning challenges teachers

As seen in the visualization, the most dominant challenges are low student interest, limited media, student laziness, and an unconducive classroom atmosphere. Words such as low interest, media, combating laziness, and classroom atmosphere appear in large font sizes, indicating high frequency of mention by respondents. This indicates that student psychology and the availability of learning media are the main factors hindering the success of deep learning. The study to contribute to science learning lies in the development and dissemination of an Interactive Digital Physics Module (IDMP) that holistically enhances teachers' Scientific Inquiry Literacy (SIL) through a mixed-methods approach. This study addresses three key gaps in the literature: (1) the lack of digital modules that specifically train teachers' inquiry skills (rather than just students' content), (2) the limited integration of interactive simulations with authentic inquiry pedagogy, and (3) the absence of a community-of-practice (CoP)-based dissemination model in the Indonesian context. Practically, the IDMP offers a contextual solution to the challenges of immersive learning by integrating virtual labs, inquiry scaffolding, and collaborative features aligned with the Merdeka curriculum and the Pancasila Student Profile. Its theoretical contribution is embodied in a novel framework that connects teachers' digital literacy, inquiry pedagogy, and sustainable dissemination. This research not only provides empirical evidence on the effectiveness of technology-based SIL training but also paves the way for a cultural transformation of science learning toward a more exploratory and evidence-based approach.

Furthermore, several other obstacles emerged, such as low student response, teacher unpreparedness, differences in student abilities, and limited time for the learning process. These conditions illustrate that the implementation of the Deep Learning Curriculum cannot be optimal without the support of relevant media and a pedagogical approach that adapts to student characteristics. In this context, the use of the Interactive Digital Module Physics (IDMP) is one alternative solution offered in this community service program. The IDMP is designed to support scientific inquiry-based physics learning with an interactive and visual approach. Through the IDMP, students can engage in experimental simulations, data exploration, and digital observation of physical phenomena. This directly contributes to fostering student interest in learning and active participation in the classroom. Teacher training and mentoring in implementing the IDMP yielded positive results. Teachers became better able to design lessons that facilitate student curiosity, stimulate scientific inquiry, and guide the investigative process. Thus, the IDMP was able to address identified challenges, particularly in terms of enhancing media, increasing student motivation, and creating a more active and immersive classroom atmosphere.

Preliminary results indicate an 83.3% adoption rate for the IDMP, with 73.3% of teachers successfully integrating it into their Lesson Plans. This finding indicates that the IDMP is not only feasible to use but also relevant to teachers' needs in developing inquiry-based learning. The IDMP Adoption Rate reveals the level of digital module adoption by teachers using four key indicators. The data shows that 83.3% of teachers consistently use the IDMP in their lessons, indicating high acceptance of this technology. This high rate is supported by the module's user-friendly design and the relevance of its content to the deep learning curriculum, as proposed.

The integration indicator with the Lesson Plan reached 73.3%, reflecting the ease of adapting the IDMP into pedagogical planning. The TPACK (Technological Pedagogical Content Knowledge) framework, where teachers successfully combined technological, pedagogical, and content knowledge in a balanced manner. However, the lower percentage of interactive feature utilization (60.0%) suggests the need for more intensive training to optimize the simulation and automatic feedback functions. To further explore these quantitative findings, semi-structured interviews were conducted with ten participating teachers with varying backgrounds and experiences. Interview results indicated that the low utilization of interactive features (60%) was largely due to teachers' limited time to fully explore IDMP features, as well as their unfamiliarity with active and exploration digital learning approaches. Several teachers stated that they were more focused on completing curriculum material, resulting in underutilization of interactive features such as simulations and digital quizzes.

Collaboration among teachers in using IDMP was recorded at 50.0%, indicating the untapped potential for developing a community of practices. According to Wenger (1998), such collaboration is crucial for sharing implementation strategies and solving technical problems. This low rate may be influenced by time constraints or a lack of institutional incentives, necessitating intervention through collaborative workshops or a digital resource sharing platform. The Figure 3 shows the complete IDMP Adoption Rate.

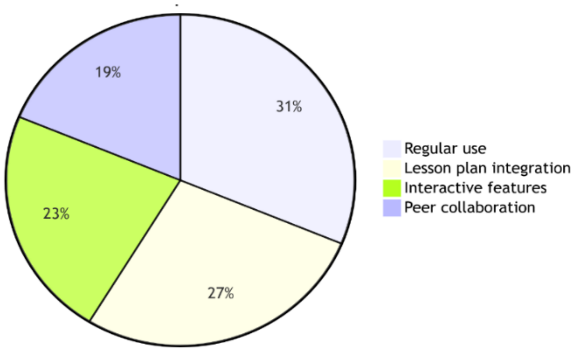

Figure 3. IDMP Adoption Rate

Overall, this graph demonstrates that the IDMP meets the criteria for usability and utility in the context of science education. However, disparities between indicators, such as high levels of routine use but low levels of collaboration, highlight the importance of a holistic approach to educational technology dissemination, encompassing technical training, administrative support, and professional networking. The results of this study demonstrate that the Interactive Digital Physics Module (IDMP) significantly improves science teachers' Scientific Inquiry Literacy (SLI), with an N-Gain increase of 47.6%-60.5%. This finding aligns with previous research suggesting that interactive simulation-based digital modules can strengthen conceptual understanding and inquiry skills. However, the uniqueness of this study lies in its focus on teachers aged 35-55, a group often less engaged in technology adoption than younger generations. The 83.3% adoption rate demonstrates that the user-friendly design of the IDMP successfully addresses digital literacy challenges in this age group.

3.2. Implementing the IDMP to Improve Scientific Inquiry Literacy

The improvement in teachers' scientific inquiry literacy skills after implementing the IDMP was significant across the three main aspects measured: designing investigations, guiding inquiries, and evaluating scientific processes. Pre-test results indicated that teachers' initial scores were moderate, with scores of 40%, 35%, and 30%, respectively. This reflects teachers' limited understanding of how to comprehensively implement a scientific inquiry approach in the learning process. After implementing the physics-based interactive digital module (IDMP), there was a significant increase in post-test scores across all aspects. Scores increased to 65% for designing investigations, 58% for guiding inquiries, and 52% for evaluating scientific processes. These data demonstrate that an interactive digital approach based on contextual physics content can improve teachers' conceptual understanding and pedagogical skills in facilitating discovery learning. The Figure 4 shows the improvement of teachers' scientific inquiry literacy after implementing IDMP

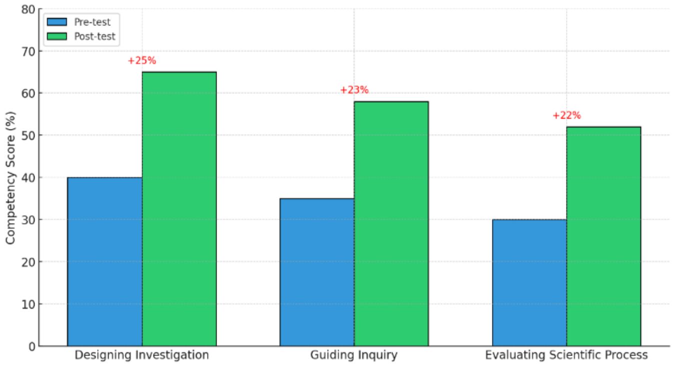

Figure 4. Improvement of Teachers' Scientific Inquiry Literacy After Implementing IDMP

The implementation of the Interactive Digital Physics Module (IDMP) demonstrated a significant positive impact on improving teachers' Scientific Inquiry Literacy (SLI). Pre-test analysis revealed that teachers' initial abilities in all three aspects designing investigations (40%), guiding inquiries (35%), and evaluating the scientific process (30%) were still in the moderate category, indicating gaps in mastery of a holistic inquiry approach. However, after the IDMP-based intervention, substantial improvement occurred in the post-test, with the highest achievement in designing investigations (65%), followed by guiding inquiries (58%), and evaluating the scientific process (52%). This improvement was not only statistical (N-Gain 25-35%) but also reflected teachers' pedagogical transformation in designing inquiry-based learning, supported by interactive simulations and scaffolding features within the module. These findings align with the technological pedagogical content knowledge theory, which emphasizes the integration of technology to strengthen practice. The Figure 5 shows the improvement in scientific inquiry literacy (SIL) after teachers used the IDMP

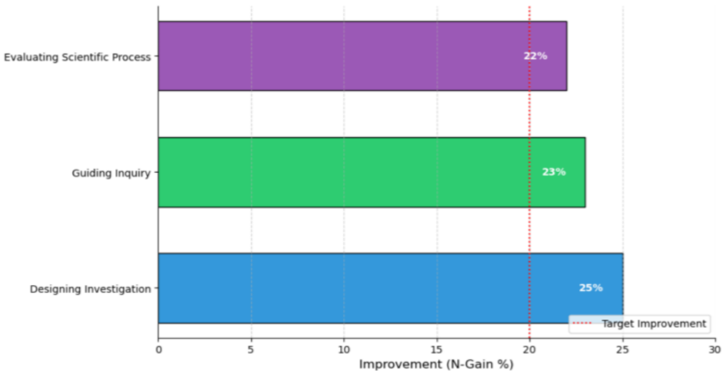

Figure 5. Improvement in Scientific Inquiry Literacy (SIL) after teachers used the IDMP

Based on Figure 5 the research data shows an increase in teachers' Scientific Inquiry Literacy (SIL) after implementing the Interactive Digital Physics Module (IDMP) across three main dimensions. The highest increase occurred in Designing Investigations (25%), followed by Guiding Inquiries (23%), and Evaluating Scientific Processes (22%). All three dimensions exceeded the minimum target of 20% improvement, with relatively small differences between dimensions (22-25%). This indicates that the IDMP is consistently effective in improving various aspects of teachers' scientific inquiry competencies, particularly in designing investigations supported by the interactive simulation features in the module.

The heterogeneous improvement across aspects with the highest achievement in designing investigations and the lowest in evaluating scientific processes highlights two critical implications. First, the success of the IDMP in supporting investigation design (65%) demonstrates the effectiveness of the digital simulation feature in developing teachers' hands-on skills. Second, the remaining challenges in the evaluation aspect (52%) suggest the need for strengthening automated feedback features and specific training in analyzing scientific evidence. At a macro level, these findings reinforce the role of contextual digital media as a catalyst in 21st-century science education, particularly for teachers with late adopter characteristics (aged 35-55 years). Policy recommendations include: (1) expanding IDMP-based training with a focus on assessment literacy, and (2) developing a community of practice to share inquiry implementation strategies in the field. The IDMP Dissemination Timeline for Improving Scientific Inquiry Literacy (SIL) is shown in the following Figure 6.

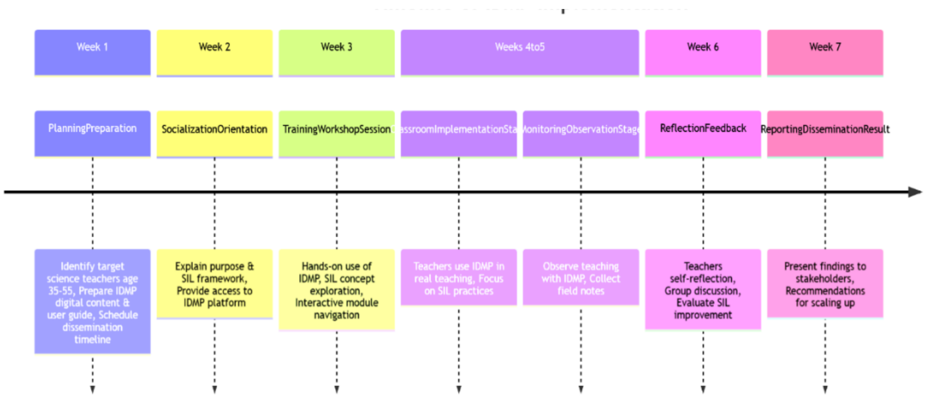

Figure 6. IDMP Dissemination Timeline for Improving Scientific Inquiry Literacy (SIL)

The dissemination process for the Interactive Digital Module Physics (IDMP) began with a comprehensive planning and preparation phase. In this initial phase, researchers identified the science teachers targeted for dissemination, namely teachers aged 35–55. Furthermore, digital content for the IDMP and a user guide for the module were systematically prepared to support the implementation of scientific inquiry-based learning. A detailed dissemination schedule was also designed to ensure that each stage ran according to the research plan.

The next phase included outreach activities, training, and practical workshops to build teacher understanding and readiness to use the IDMP. During the outreach week, the dissemination objectives and basic concepts of Scientific Inquiry Literacy (SIL) were clearly introduced. Next, teachers participated in interactive training where they learned the features of the IDMP, simulated its use, and gained hands-on experience. This phase was crucial for equipping teachers with the skills needed to integrate the module into their teaching practices. Subsequent phases included classroom implementation, observation, and reflection and feedback. For two weeks, teachers implemented the IDMP in real-life classroom learning activities, with a primary focus on strengthening students' scientific inquiry skills. Concurrently, researchers conducted observations to record teaching strategies, challenges encountered, and student responses. In the final week, teachers reflected on their experiences and provided feedback, which was reviewed collaboratively. The overall results of this dissemination were then reported to stakeholders as a basis for decision-making and recommendations for expanding the use of the IDMP in science education.

Integrating the IDMP in Lesson Plans and Challenges in Utilizing Interactive Features, total of 73.3% of teachers successfully integrated the IDMP into their Lesson Plans (RPP), indicating a high level of acceptance. However, utilization of interactive features only reached 60%, indicating that some teachers still struggle to maximize the potential of the IDMP. Technology adoption is not always followed by optimal utilization. A unique feature of this study is the identification of a gap between adoption and in-depth implementation, which suggests the need for more intensive technical and pedagogical training. Collaboration Between Teachers and the Need to Strengthen Communities of Practice (CoP), The level of collaboration between teachers was recorded at 50%, indicating that professional interaction remains limited. This finding reinforces the importance of building CoP to support the exchange of ideas and experiences. Interestingly, this study revealed that although the IDMP is equipped with collaborative features, teachers tend to use them individually. Therefore, developing a structured discussion forum and an experimental data bank within the IDMP could be an innovative solution to enhance collaboration.

The N-Gain scores obtained were 25% (designing investigations), 23% (guiding inquiries), and 22% (evaluating scientific processes), respectively, which fall into the moderate to high improvement category. This improvement indicates that the IDMP not only strengthens content aspects but also supports teachers in practicing inquiry-based scientific learning approaches (Wibowo & Nasbey, 2024; Kamarudin & Noor, 2024). The use of digital elements in the IDMP allows teachers to experience inquiry simulations, explore phenomena, and develop more reflective and evidence-based learning strategies.

Overall, these results support the importance of integrating digital technology into teacher training, particularly through the development of interactive, content-based modules. The IDMP has been shown to bridge the gap between the theory and practice of scientific inquiry in the classroom and has had a significant impact on improving teachers' scientific literacy. The implications of these findings encourage the expanded use of the IDMP in teacher professional development programs to improve the quality of science learning in schools. Improvements in each aspect of teachers' SIL after learning to use the IDMP are shown in the following figure.

These findings reinforce that the digital approach through the IDMP successfully addresses the challenges of teacher professional development, particularly in the context of inquiry-based learning. Although the lowest improvement occurred in the scientific process evaluation aspect (22%), the insignificant differences in other dimensions indicate that the module has a balanced impact. This success is supported by the IDMP's design, which facilitates independent learning and hands-on practice, while highlighting the need for further strengthening of the automated feedback feature to assist teachers in evaluating the scientific process more effectively. IDMP as a Support for Deep Learning: The effectiveness of the IDMP in supporting deep learning is demonstrated by the module's ability to facilitate the exploration of physics concepts through interactive simulations (Annida et al., 2025; Darman et al., 2023). The digital technology can deepen understanding if designed with a constructivist approach. The uniqueness of this study lies in testing the IDMP in the context of teacher training, not just student training, thus providing a new contribution to educator professional literacy.

Based on the findings, this study recommends strengthening collaborative features such as discussion forums and experimental data banks to support sustainable practices. This recommendation differs from similar studies, which typically focus on content enrichment, as this study emphasizes the socio-communicative aspects of teacher professional development. Thus, the IDMP serves not only as a learning tool but also as a platform for knowledge sharing among teachers, making it a holistic solution for improving SIL.

4. Conclusion

The dissemination of the Interactive Digital Module Physics (IDMP) effectively improves science teachers' Scientific Inquiry Literacy (SIL) in an immersive learning context. The module adoption rate reached 83.3%, with 73.3% of teachers successfully integrating the IDMP into their lesson plans. Significant improvements in scientific inquiry literacy were demonstrated through N-Gain scores of 25% in designing investigations, 23% in guiding inquiries, and 22% in evaluating scientific processes. These findings reinforce the contribution of the IDMP as a digital learning tool that not only enriches teachers' learning experiences but also supports the implementation of an immersive learning curriculum through an inquiry-based approach. This module serves as a means of enhancing teachers' pedagogical competencies through contextual and accessible interactive simulations. However, this study is limited in terms of geographic coverage and institutional setting, which limited the sample to science teachers in the Jakarta area. Therefore, it is recommended that future research expands the participant population to other regions and evaluate the effectiveness of the IDMP in other educational contexts. In addition, the development of collaborative features such as discussion forums and experimental data banks is recommended to support the sustainability of inquiry-based learning practices among teachers.

Author Contributions

To ensure transparency, the contributions of each author to this article are described as follows: Firmanul Catur Wibowo: Conceptualization, Methodology, Project Administration, Original drafting, Supervision. Hadi Nasbey: Data curation, Formal analysis, Validation, Review & editing. Dina Rahmi Darman: Investigation, Resources, Visualization, Original drafting. Iffa Hamidah: Software, Validation, Review & editing. Thomas EDP: Formal analysis, Visualization, Methodology. Daniel Steeven:Data curation, Investigation, Original drafting. Muhammad Suryauno Mahmuda: Resources, Software. Muhammad Abrar Asyrafy Yacobi: Investigation, Visualization, Original drafting. Beken Arymbekov (Satbayev University, Kazakhstan): Data analysis, Cross-cultural validation, Review. All authors have read and approved the manuscript.

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Declaration of Conflicting Interests

The authors declare no conflicts of interest, either financial or non-financial, in this research. They have no relationships or affiliations with any parties that could affect the objectivity or integrity of the research results and conclusions presented in this article.

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