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Need Analysis of a Physics E-Book on Global Warming Based on the Dual Space Inquiry Framework to Improve Students' Scientific Literacy

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ABSTRACT

This research is motivated by the low scientific literacy of students as indicated by the PISA 2022 results, as well as the continued dominance of printed teaching materials in schools. This condition limits students' opportunities to engage in scientific thinking, interpret data, and use scientific evidence effectively. The purpose of this study is to analysis the need for developing an interactive e-book based on the Dual Space Inquiry Framework (DSIF) on the topic of global warming to improve students' scientific literacy. The study employed a needs analysis approach within the Analysis stage of the ADDIE development model by collecting quantitative data related to scientific literacy indicators and the frequency of teaching material usage. The analysis shows that all scientific literacy indicators fall into the low category with an average score of 70.3%, particularly in the abilities to interpret data and evaluate scientific arguments. The data on teaching material usage also reveal a dominance of printed books at 91%, while digital teaching materials are used by only 37% of students and interactive e-books by merely 12%. These findings not only illustrate the low level of scientific literacy but also highlight an urgent need for more interactive digital learning media. Based on this analysis, the Analysis stage of ADDIE emphasizes the necessity of developing a DSIF-based interactive e-book as an innovative solution that will proceed to the Design and Develop stages to produce teaching materials capable of supporting inquiry, conceptual understanding, and scientific thinking skills.

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INTRODUCTION

Twenty-first-century learning requires students to acquire critical, creative, collaborative, and communicative thinking skills as part of essential global competencies (Herlina et al., 2021). The rapid development of digital technology also demands that schools adapt to continuous changes in the learning process. Technology enables students to access a wider and more diverse range of learning resources compared to traditional printed materials. Integrating technology into learning activities can increase interactivity and support learner-centered approaches (Munir, 2020). Teachers, as facilitators, are also required to integrate pedagogy and technology to ensure learning remains relevant to contemporary needs. Therefore, technology integration in learning has become a fundamental requirement in twenty-first-century education.

Learning physics, particularly global warming, requires an approach that integrates scientific literacy, inquiry, and digital technology. The Dual Space Inquiry Framework (DSIF)-based learning model allows students to conduct inquiry in two spaces simultaneously: a mental space for analyzing concepts and a physical space for conducting experiments or simulations. The use of interactive e-books based on DSIF is believed to facilitate the visualization of abstract concepts, provide virtual experimental experiences, and increase student motivation and understanding. Thus, the development of DSIF e-books is not only relevant to supporting physics learning on global warming but also aligns with efforts to improve scientific literacy in the digital era.

Global warming is an increasingly pressing environmental issue at both the global and national levels. According to the IPCC AR6 Report (2023), the Earth's average surface temperature has increased by 1.1°C since the pre-industrial era, with a projected increase of 1.5–2°C by mid-century if greenhouse gas emissions are not immediately curbed. In Indonesia, the impacts of global warming are evident through the increasing frequency of floods and droughts, rising sea levels on the north coast of Java, and forest fires that produce smoke pollution and impact public health. Forest fires in Kalimantan and Sumatra, for example, have affected regional air quality and threatened local ecosystems and livelihoods. Amid these environmental challenges, 21st-century scientific literacy is crucial. The 2022 PISA results show that Indonesia's scientific literacy scores are below the OECD average, particularly in students' ability to interpret data, formulate hypotheses, and apply scientific concepts in real-world contexts. National surveys also highlight students' low skills in inquiry, critical thinking, and utilizing technology to understand scientific concepts.

Global warming is an environmental issue that urgently needs to be understood by students because it directly affects the sustainability of life on Earth. This phenomenon occurs due to the increasing concentration of greenhouse gases that trap heat in the Earth's atmosphere (IPCC, 2021). Its impacts can be observed through extreme climate changes, rising sea levels, and the disruption of natural ecosystems (NASA, 2020). Understanding global warming is essential in physics learning because it relates to key concepts such as energy, radiation, and Earth's energy balance. However, this topic is often perceived as abstract, making it challenging for students to connect scientific concepts with real-world environmental phenomena (Putri et al., 2020). These challenges indicate the need for learning approaches that connect physics concepts with observable environmental events.

Scientific literacy refers to students' ability to understand scientific phenomena, interpret evidence, and make informed decisions based on data (Rizki & Nursyamsi, 2020). This competency is essential in physics education because it helps students construct meaningful understanding of abstract scientific concepts. In the context of environmental issues such as global warming, scientific literacy plays an important role in building students' awareness and scientific reasoning. Reports from national assessments show that the scientific literacy level of Indonesian students remains relatively low and requires serious attention (Ministry of Education, Culture, Research, and Technology, 2023). This condition illustrates that current science learning strategies need improvement to become more evidence-based and contextually relevant. Therefore, strengthening scientific literacy must be a primary focus in the development of physics learning materials.

Based on the demands of twenty-first-century learning, students require instructional materials that support critical thinking and problem-solving abilities. Effective learning materials should integrate technology to create interactive and engaging learning experiences (Herlina et al., 2021). In physics learning—particularly on the topic of global warming—learning materials must connect scientific concepts with real-world environmental observations (Sari et al., 2021). In addition, learning materials should facilitate inquiry-based activities that allow students to construct knowledge through scientific

exploration (Rahmawati & Hidayat, 2022). The alignment of learning materials with scientific literacy goals is also crucial for enhancing students' understanding of environmental issues. Therefore, developing digital learning materials that meet students' needs is a strategic step toward improving the quality of physics education.

One approach that can be used is Dual Space Inquiry Framework (DSIF), which integrates conceptual spaces (conceptual space) and inquiry space (inquiry space) to develop scientific understanding and higher-order thinking skills (Linn et al., 2020; Park et al., 2022). The use of DSIF-based e-books is expected to improve students' scientific literacy through exploratory, reflective, and contextual activities. Furthermore, this digital medium aligns with the characteristics of the digital generation, which is more responsive to interactive learning (Gunawan et al., 2023; Susanti et al., 2022). Therefore, a needs analysis for the development of DSIF-based physics e-books on global warming is crucial to ensure the media's suitability to student characteristics, learning objectives, and 21st-century scientific literacy indicators (Kemendikbudristek, 2022; Fitriani & Mulyani, 2023).

Initial observations at SMAN 1 Bayang, Pesisir Selatan Regency, showed that physics learning was still dominated by lecture methods and the use of printed textbooks. Teachers reported that limited interactive media and digital teaching materials in accordance with the Independent Curriculum were obstacles in facilitating inquiry activities (Kemendikbudristek, 2022). A questionnaire survey of 10th-grade students showed that 70% of students had difficulty understanding global warming material due to its abstract nature, infrequent experiments, and a lack of connection between the concept and everyday life (Putri et al., 2020; Rahmawati & Hidayat, 2022). Teacher also conside students' low scientific literacy to be a major challenge, particularly in understanding environmental phenomena such as the greenhouse effect and global warming. Interactive digital media are needed to bridge students' conceptual and empirical understanding (Handayani et al., 2023; Gunawan et al., 2023). One alternative is a physics-based e-book Dual Space Inquiry Framework (DSIF), which integrates conceptual space and empirical space to connect theory and learning experiences (Linn et al., 2020; Zhang, 2017).

E-books not only serve as a substitute for printed textbooks but also allow for the integration of various multimedia elements such as animation, video, simulations, and interactive quizzes, which can increase student motivation and engagement in the learning process (Prasetyo & Sutopo, 2021). With the support of digital technology, e-books can be an effective tool for facilitating inquiry-based science learning and strengthening students' scientific thinking skills. To make e-book development more meaningful and effective, these teaching materials need to be integrated with learning models oriented toward developing scientific thinking skills. One relevant model is the Dual Space Inquiry Framework (DSIF) developed by Novitra et al. (2025). The DSIF model combines two thinking spaces: conceptual space and empirical space. Based on this foundation, this study aims to analyze the need for developing a physics e-book based on the Dual Space Inquiry Framework (DSIF) on global warming material to ensure the suitability of the media to the characteristics of students, the demands of twenty-first century learning, and indicators of scientific literacy.

METHODS

This research used a research and development (R&D) method with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, modified to include a practicality test (Branch, 2009; Sugiyono, 2021). This model was chosen because it provides systematic steps in developing valid, practical, and effective learning media. The research was conducted in the odd semester of the 2024/2025 academic year at SMA Negeri 1 Bayang, Pesisir Selatan Regency, West Sumatra. The goal of this research was to produce a Physics e-book based on

the Dual Space Inquiry Framework (DSIF) on Global Warming to improve the scientific literacy of 10th-grade Phase E students. The research subjects included 30 10th-grade students as product users and two expert validators, a material expert and a media expert, to assess the feasibility of the developed e-book.

The research phase began with a needs analysis, including curriculum analysis, student characteristics, and the learning media used by teachers at the school (Prawiradilaga, 2021; Widyastuti et al., 2022). The needs analysis was conducted through interviews with Physics teachers and questionnaires distributed to students to obtain data on the suitability of the teaching materials used to meet the demands of 21st-century learning. The results of the needs analysis served as the basis for designing a DSIF-based e-book, which integrates two thinking spaces: conceptual and epistemic, to encourage scientific inquiry and improve scientific literacy (Duit & Treagust, 2023; Sari & Rahmawati, 2021). The instruments used included an expert validation sheet, teacher and student needs questionnaires, and a practicality sheet. The validation sheet was used to assess content, language, presentation, and compliance with the DSIF model (Ratnasari et al., 2023). The practicality questionnaire assessed the e-book's ease of use, appeal, and usefulness in learning activities (Pratama & Lestari, 2022).

Data were collected through observation, questionnaires, and documentation, then analyzed descriptively using quantitative and qualitative methods (Sugiyono, 2021; Creswell & Creswell, 2018). Validation and practicality scores were calculated using a four-level Likert scale and converted into categories of very valid, valid, less valid, and invalid (Mawardi et al., 2021). Qualitative data, in the form of validator comments and suggestions, were used to refine and improve the product. With these procedures, this research is expected to produce a Physics e-book based on the Dual Space Inquiry Framework (DSIF) that is valid, practical, and potentially effective in improving students' scientific literacy on the topic of Global Warming, while also supporting the implementation of the Independent Curriculum, which focuses on meaningful and student-centered learning (Kemendikbudristek, 2022; Ningsih et al., 2023).

RESULTS AND DISCUSSION

Results

Analysis of scientific literacy needs

Scientific literacy is students' ability to understand, evaluate, and apply scientific knowledge in everyday life. This ability encompasses several indicators, namely understanding scientific concepts, interpreting data, applying knowledge to solve problems, and developing critical thinking skills. Improving scientific literacy is crucial so that students not only memorize theories but also connect scientific concepts to real-world phenomena, including the topic of Global Warming. Each of these indicators serves as the basis for assessing students' abilities comprehensively and in-depth. By understanding the level of mastery of each indicator, teachers can design more targeted learning strategies. Therefore, indicator-based scientific literacy evaluation is a crucial first step in developing effective teaching materials. Table 1 presents the results of the analysis of students' scientific literacy abilities based on predetermined criteria.

Table 1. Results of Student Science Literacy Analysis

No	Scientific Literacy Indicators (PISA 2022)	Score	Category	Percentage (%)
1	Identifying scientific issues	70	Low	70%
2	Explaining scientific phenomena	74	Low	74%
3	Interpreting data and scientific evidence	69	Low	69%
4	Using scientific evidence	71	Low	71%

5	Connecting science to everyday life	75	Low	75%
6	Evaluating scientific arguments	73	Low	73%
7	Applying scientific concepts in real contexts	72	Low	72%
8	Making science-based decisions	74	Low	74%
	Overall average	70,3	Low	70%

The analysis of the PISA 2022 scientific literacy indicators shows that all aspects of students' scientific abilities fall within the low category, with an average score of only 70.3%. This condition aligns with the official PISA report, which states that Indonesia's scientific literacy performance remains below the OECD average and has shown stagnation in recent years (OECD, 2023). The low scores on indicators such as identifying scientific issues and explaining scientific phenomena indicate that the learning process is still dominated by teacher-centered approaches that emphasize memorization rather than problem-solving and phenomenon analysis (Prastowo, 2020). The indicator interpreting data and scientific evidence, which received the lowest score of 69%, further reinforces the finding that students have limited experience in reading graphs, analyzing tables, or drawing conclusions based on empirical evidence. This is consistent with previous studies showing that Indonesian students' scientific thinking skills remain limited due to the minimal use of experiments and data interpretation activities in science learning (Hidayat & Widodo, 2021).

The low performance in using scientific evidence and evaluating scientific arguments demonstrates that students are not yet accustomed to constructing data-based arguments. In fact, the ability to use evidence is a core component of modern scientific literacy (Bybee, 2015). Although the indicator connecting science to everyday life obtained a relatively higher score of 75%, it still falls within the low category, indicating that students have not fully grasped the relevance of science in real-life contexts. This is supported by other studies showing that students tend to understand concepts theoretically but struggle to apply them in real-world situations (Sukmawati et al., 2022). Furthermore, the limited use of digital learning materials in schools prevents students from experiencing interactive learning, even though digital resources have been proven to enhance conceptual understanding, data interpretation, and critical thinking skills (Herlina et al., 2021). These conditions show that low scientific literacy is not solely caused by students' abilities but is also linked to the characteristics of the learning materials and instructional models used.

These findings reinforce the urgency of implementing innovative learning approaches such as the Dual Space Inquiry Framework (DSIF), which integrates mental and physical inquiry spaces to enhance students' inquiry skills and scientific literacy. Inquiry-based approaches have been proven to improve students' abilities in identifying problems, using scientific evidence, evaluating arguments, and making informed scientific decisions. Thus, the analysis of the PISA table not only illustrates the low level of scientific literacy but also emphasizes the need for transforming science learning through the use of interactive digital learning materials designed to develop twenty-first-century skills. The implementation of DSIF in the form of an interactive e-book is expected to provide a more meaningful learning experience and support the continuous development of students' scientific competencies.

Analysis of Learning Material Issues

In addition to analyzing students' scientific literacy skills, this study also evaluates the utilization of learning material models used in the learning process. The data show that most students still rely on printed textbooks, while technology-based learning resources or interactive modules are rarely used. This condition indicates limited access to learning materials that support inquiry activities and interactive concept reinforcement. In fact, digital

learning materials and modules based on the Dual Space Inquiry Framework (DSIF) have strong potential to enhance students' conceptual understanding and critical thinking skills. Evaluating the learning material models is essential to determine the extent to which the available instructional media align with students' needs and learning objectives. Table 2 presents the results of the analysis of students' needs regarding the use of various learning material models in the classroom.

Table 2. Results of the Analysis of Students' Learning Material Needs

No	Type of Learning Material	Frequency of Use	Description
1	Printed Textbook	91%	Dominantly Used
2	Digital Learning Material	37%	Underutilized
3	Interactive E-Book	12%	Very Rarely Used

The analysis of the learning material usage table shows that printed textbooks remain the most dominant learning resource, with a usage rate of 91%. The high dependence on printed books indicates that the learning process in schools is still centered on conventional materials and has not fully shifted toward technology-based learning. This finding aligns with several studies reporting that many schools in Indonesia have not yet optimized the use of digital tools as instructional media, either due to limited infrastructure or insufficient teacher training (Herlina et al., 2021). Meanwhile, digital learning materials are used only 37% of the time, indicating that their utilization remains low despite increasing access to digital technology. This condition suggests that the integration of technology into learning has not been implemented effectively, even though digital learning materials have been proven to enhance interactivity, student engagement, and deeper scientific conceptual understanding (Munir, 2020).

The use of interactive e-books is even lower, at only 12%, indicating that students rarely experience learning through dynamic and interactive media. In fact, interactive e-books offer various features such as simulations, animated videos, hyperlinks, and automated assessments, all of which have been shown to improve learning motivation and students' scientific literacy (Arsyad, 2022). The low utilization of interactive e-books highlights a gap between the potential of modern educational technology and the actual learning practices implemented in schools. Moreover, this low percentage reinforces the finding that the development of digital learning materials is still not a primary priority in many educational settings. These conditions indicate the need to develop more innovative instructional models and materials, including an interactive e-book based on the Dual Space Inquiry Framework (DSIF), to create learning experiences that are more contextual, engaging, and effective in increasing active student participation.

Analysis of Problems in the Global Warming Material

In addition to scientific literacy skills and the evaluation of learning materials, this study also highlights the challenges students face in understanding the topic of Global Warming. Identifying these problems is essential to determine the learning barriers that affect conceptual understanding and critical thinking skills. Such data can assist teachers and learning material developers in designing more targeted instructional strategies. Several common issues identified relate to difficulties in understanding scientific concepts, limited availability of digital learning materials, and low student motivation. The results of this problem identification are presented in detail in Table 3, providing a clear overview of the aspects that need improvement within the learning process.

Table 3. Analysis of Problems in the Global Warming Material

No	Students' Problems in Global Warming Material	Percentage (%)
1	Difficulty connecting the concept of global warming to everyday life	75%
2	Difficulty interpreting graphs or scientific evidence related to global warming	69%
3	Difficulty making science-based decisions to prevent the impacts of global warming	74%
4	Lack of learning motivation to understand global warming material in depth	70%

Based on Table 3, most students experience difficulties in connecting the concept of global warming to everyday life, with a percentage of 75%. This indicates that although students may understand the basic theory, they struggle to see the relevance of the material to real-world phenomena, such as local climate change, natural disasters, or environmental impacts in their surroundings. This problem is closely related to the low scientific literacy indicator of linking science with daily life. Another contributing factor is the limited availability of interactive learning materials capable of presenting simulations or real examples of global warming. Therefore, learning strategies that emphasize real-life contexts are essential to strengthen the connection between concepts and students' experiences.

In addition, 69% of students experience difficulty interpreting graphical data or scientific evidence related to global warming, such as annual average temperature trends or CO_2 concentration levels. This reflects students' low ability to understand scientific evidence, analysis data, and draw fact-based conclusions. Such difficulties can hinder their ability to engage in scientific inquiry and critical thinking. The lack of practice in reading visual data and the limited use of DSIF-based learning materials are major factors influencing this challenge. Thus, developing interactive modules equipped with data visualizations is crucial for improving students' interpretation skills.

Other issues appear in the indicators of making science-based decisions and students' learning motivation, with percentages of 74% and 70% respectively. These findings indicate that students still struggle to apply the concept of global warming to propose appropriate mitigation or adaptation actions. Low motivation also affects active participation in learning and the depth of material comprehension. The use of DSIF-based interactive digital learning materials can serve as an effective solution, as they provide contextual learning experiences and stimulate active student engagement. Therefore, such interventions not only improve conceptual understanding but also enhance critical thinking, scientific application, and overall scientific literacy.

Analysis of Problems in the Learning Model

In addition to scientific literacy and learning materials, this study also evaluates the learning model implemented in the Global Warming topic, particularly concerning students' preferences for inquiry- and experiment-based methods. The questionnaire results indicate that most students prefer learning through experiments, discussions, and inquiry activities, as these methods are considered more engaging and helpful for deepening conceptual understanding. However, teachers still tend to rely on lecture-based methods learning focuses on the teacher. Identifying these issues is essential to understand the barriers to implementing learning strategies that support scientific literacy and conceptual mastery. Table 4 presents a summary of students' problems related to the learning model and its alignment with their learning preferences.

Table 4. Analysis of Problems in the Learning Model

No	Problems in the Learning Model
1	Teachers still predominantly use the lecture method.
2	There are minimal inquiry and experimental activity, even though students prefer these models.
3	There is a lack of real-world context applied in learning.
4	Students are less actively involved due to less interactive teaching methods.

Table 4 shows that one of the main problems is that teachers still predominantly use the lecture method, even though the questionnaire results indicate that students prefer experiment-based and inquiry-based learning models. This situation leads to low student engagement and reduced participation during learning. Inquiry-based learning emphasizes exploration, observation, data analysis, and evidence-based decision-making, all of which are difficult to implement when lecture-based instruction dominates. As a result, students' understanding of Global Warming concepts becomes limited, and their critical-thinking skills are not optimally developed. A shift toward inquiry-based strategies is needed to align the learning method with students' needs and preferences.

In addition, the limited implementation of inquiry and experimental activities becomes an obstacle despite students' preference for these methods. Many students rarely conduct observations, experiments, or simulations related to Global Warming phenomena, causing difficulties in interpreting data and understanding scientific evidence. Learning modules based on the Dual Space Inquiry Framework (DSIF) can help students learn actively in two spaces: mental and physical. These structured inquiry activities allow students to connect concepts with real-life contexts and enhance critical-thinking skills. In other words, the implementation of learning models that match student preferences can improve both scientific literacy and conceptual understanding.

Another issue lies in the lack of real-world contextualization and limited student participation, which stem from less-interactive teaching methods. Much of the Global Warming material is delivered abstractly without linking it to everyday environmental phenomena, making it difficult for students to interpret the concepts contextually. The integration of interactive digital learning materials and inquiry strategies can provide simulations, discussions, and experiments that stimulate active student involvement. Thus, experiment-based and inquiry-based learning models not only align with student preferences but are also effective in improving scientific literacy and critical-thinking skills. Shifting from lectures to inquiry-based approaches becomes a strategic step for enhancing learning quality.

Discussion

The learning of Global Warming material in Grade X shows several challenges that affect students' conceptual understanding and scientific literacy. Based on the analysis of scientific literacy, most indicators fall into the low category, with the percentage of students who have not reached maximum competence ranging from 69% to 75%. This indicates that students experience difficulties in identifying scientific issues, interpreting data and evidence, connecting science to everyday life, and making science-based decisions. This condition highlights the need for learning strategies that emphasize critical-thinking activities, data interpretation, and the application of scientific concepts in real-world contexts, which are the core of twenty-first-century scientific literacy. In addition, the evaluation of the learning materials used shows that conventional learning materials do not fully support dual-space inquiry activities (mental and physical). Interactive digital learning materials based on the Dual Space Inquiry Framework (DSIF) provide a potential alternative

because they can enhance student engagement, offer real conceptual exploration experiences, and facilitate deeper understanding of the material.

The analysis of student problems also reveals major obstacles in understanding Global Warming, including difficulties in connecting concepts to everyday life, interpreting scientific data and evidence, and making science-based decisions. These issues are closely related to low scientific literacy and the limited use of inquiry-based practices in learning. The lack of real-world context and limited student engagement make it difficult for them to interpret Global Warming concepts contextually, resulting in shallow understanding. These findings emphasize the importance of implementing contextual and inquiry-based learning strategies to improve the quality of students' understanding.

Furthermore, the evaluation of the learning model shows a gap between students' preferences and teachers' instructional practices. The student needs questionnaire indicates that learners prefer experimental methods, discussions, and inquiry activities, while teachers still predominantly use lecture-based methods. A learning model that is too teacher centered limits students' opportunities to ask questions, observe, and analyze data, thereby reducing engagement and hindering conceptual understanding of Global Warming. The limited use of real-world contexts and experimental activities further strengthens students' difficulties in interpreting data, connecting concepts to life, and making science-based decisions.

By integrating DSIF-based interactive digital learning materials and inquiry-based instructional strategies, students can learn actively in two spaces—mental and physical—enhancing their conceptual understanding, critical-thinking skills, and scientific literacy. The implementation of inquiry approaches also aligns learning with students' preferences, increasing motivation and engagement. Overall, these findings emphasize that effective Global Warming instruction must combine interactive learning materials, contextual approaches, and inquiry-based strategies so that students can understand concepts deeply, connect science to real-life situations, and develop critical-thinking skills for the twenty-first century.

CONCLUSION

Based on the results of the analysis, students' scientific literacy skills in the Global Warming topic are categorized as low, particularly in indicators related to connecting science to real-life contexts, interpreting scientific data and evidence, and making science-based decisions. This condition indicates the need for learning strategies that emphasize active engagement, data analysis, and the application of concepts in real-world contexts. Conventional learning materials do not fully support inquiry activities; therefore, the development of interactive digital learning materials based on the Dual Space Inquiry Framework (DSIF) is highly recommended. In addition, the currently dominant lecture-based instructional model does not align with students' preferences for experiments, discussions, and inquiry activities. By integrating inquiry-based learning approaches and interactive learning materials, students can improve their conceptual understanding, scientific literacy, and critical-thinking skills comprehensively.

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