



ANALYSIS OF PHYSICS LEARNING MEDIA NEEDS FOR GRADE 11 THERMODYNAMICS: THE URGENCY OF DIGITAL AND CONTEXTUAL INSTRUCTIONAL MATERIALS

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Received: 29 06 226. Accepted: 28 07 2026. Published: 07 2026

Abstrak

Penelitian ini bertujuan untuk menganalisis kebutuhan pengembangan bahan ajar fisika guna meningkatkan literasi sains peserta didik. Penelitian deskriptif ini dilaksanakan di salah satu sekolah menengah atas negeri di Jakarta dengan melibatkan 51 peserta didik dan satu orang guru fisika. Data dikumpulkan melalui angket, wawancara, observasi, dan analisis dokumen. Hasil penelitian menunjukkan bahwa 68% peserta didik mengalami kesulitan dalam merancang penyelidikan ilmiah dan menginterpretasikan data. Kesulitan tersebut diperparah oleh dominannya pembelajaran berbasis ceramah serta penggunaan media pembelajaran yang bersifat statis. Selain itu, bahan ajar yang digunakan belum secara sistematis mengaitkan konsep fisika dengan fenomena kehidupan sehari-hari, teknologi, isu-isu lingkungan, dan nilai-nilai spiritual. Kebaruan penelitian ini terletak pada usulan pengembangan bahan ajar digital interaktif yang mengintegrasikan kegiatan penyelidikan, visualisasi data, dan dimensi kontekstual ke dalam pembelajaran fisika. Hasil analisis kebutuhan memberikan pedoman yang spesifik dalam menentukan struktur materi, tugas-tugas penyelidikan, fitur visualisasi data, tema-tema kontekstual, elemen pembelajaran interaktif, serta strategi penilaian yang akan diintegrasikan pada tahap pengembangan selanjutnya. Dengan demikian, bahan ajar yang diusulkan diharapkan dapat mendukung pengembangan literasi sains yang bermakna serta mempersiapkan peserta didik agar mampu merespons tantangan abad ke-21 secara adaptif.

Kata kunci: analisis kebutuhan, bahan ajar, literasi sains, pembelajaran fisika.

Abstract

This study aims to analyze the need for developing physics instructional materials to enhance students' scientific literacy. This descriptive study was conducted at a public senior high school in Jakarta and involved 51 students and one physics teacher. Data were collected through questionnaires, interviews, observations, and document analysis. The results showed that 68% of the students experienced difficulties in designing scientific investigations and interpreting data. These difficulties were exacerbated by the dominance of lecture-based instruction and the use of static learning media. In addition, the existing instructional materials did not systematically connect physics concepts with everyday phenomena, technology, environmental issues, and spiritual values. The novelty of this study lies in

proposing interactive digital instructional materials that integrate investigative activities, data visualization, and contextual dimensions into physics learning. The findings of the needs analysis provide specific guidelines for determining the content structure, investigative tasks, data-visualization features, contextual themes, interactive elements, and assessment strategies to be incorporated in the subsequent development stage. Therefore, the proposed instructional materials are expected to support meaningful scientific literacy and prepare students to respond adaptively to the challenges of the 21st century.

Keywords : need analysis, teaching materials, science literacy, physics learning

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INTRODUCTION

Indonesian students' science literacy faces serious challenges in the context of global competition. Based on the 2022 PISA results, Indonesia ranked 64th out of 81 countries, with a science literacy score of 383. This result indicates a significant decline compared with the 2018 achievement and remains below the OECD average (OECD, 2023). The consistent decline in scores highlights the urgent need for fundamental reform in science education and the development of science instructional materials. Science literacy is a critical foundation that enables students to explain phenomena scientifically, evaluate and design scientific investigations, and interpret data and evidence scientifically (OECD, 2023). It is not merely an academic indicator but also a basic ability to understand and adapt to technological advances and environmental issues in the twenty-first century (Costa dkk., 2021; Elhai, 2023).

The low science literacy achievement of Indonesian students is rooted in school learning practices that remain teacher-centered and dependent on static instructional media. Students tend to be directed to memorize formulas without understanding the essence of the concepts, particularly in physics, which involves a high level of abstraction. These instructional limitations are

reflected in students' poor data interpretation skills and their inability to draw scientific conclusions independently. Although science literacy is highly important in everyday life, the instructional materials currently used often fail to accommodate students' visual and interactive needs, making learning feel meaningless. Given the strategic role of science literacy in strengthening national competitiveness in the Industry 4.0 era, transformation of the learning system is necessary through the development of instructional materials that are science-literacy-based and contextualized (Das dkk., 2019).

Addressing the science literacy crisis requires instructional materials that can holistically integrate scientific competencies, types of knowledge—including content, procedural, and epistemic knowledge—contexts ranging from personal to global, and cognitive levels (OECD, 2023). This requires integrating science with various dimensions of life, such as technology, the environment, society, and spiritual values, so that students can view science as a relevant part of their lives. Although numerous innovations in physics instructional materials have been developed, many previous studies still demonstrate a fragmentation of competencies, with instructional materials failing to systematically integrate the global

science literacy framework into the context of students' real lives (Besche-Truthe & Seitzer, 2025; Hijriati dkk., 2021).

One factor contributing to the low quality of physics education is the use of instructional media that does not fully support students' learning needs. In practice, physics instruction is still often teacher-centered and relies on limited learning resources, causing students to receive concepts passively. A needs analysis conducted in the development of physics e-modules also indicated that the use of instructional media in schools remains limited and often depends primarily on textbooks, thereby restricting interactivity and students' learning experiences (Nilyani dkk., 2023)

These problems are particularly evident in the topic of thermodynamics. This topic requires students to understand the relationships between macroscopic quantities, such as temperature, heat, and work, and their underlying physical explanations; consequently, it is often perceived as abstract and difficult to understand (Malgieri dkk., 2016) . A systematic review of heat and temperature education also indicates that demonstrations, virtual methods, and simulations are important strategies for supporting conceptual understanding in the thermal domain (Mulyani dkk., 2023).

In this context, digital and contextual instructional materials are relevant for development in physics education. Digital instructional materials enable content to be presented visually, interactively, and flexibly, while the contextual approach helps students relate physics concepts to real-life situations. Aprianti et al. (2023) found that a contextual e-module on optical instruments produced an N-gain score of 0.788 in the experimental class, which was higher than the control class's score of 0.577. Similarly, Santoso et

al. (2023) reported that contextual phenomenon-based learning improved science literacy, with N-gain scores ranging from 82.31% to 83.92% in the topics of work and energy, momentum, and fluids. Amini and Sinaga (2021) also found that students' science literacy skills remained low, with an overall achievement of 41.53%, particularly in explaining phenomena scientifically, evaluating and designing investigations, and interpreting scientific data and evidence.

Nevertheless, previous studies have primarily examined the effectiveness of developed instructional materials or learning models. A study specifically analyzing teachers' and students' needs as a basis for designing contextual digital instructional materials for Grade 11 thermodynamics is still needed. Therefore, this study conducted a needs analysis to identify learning conditions, teachers' and students' difficulties, and the characteristics of the required instructional materials, investigative activities, interactive features, data visualization, and learning contexts. Accordingly, this study aims to analyze the needs for developing digital and contextual physics instructional materials on Grade 11 thermodynamics as a foundation for developing instructional materials in the subsequent stage.

METHODE

This study was a preliminary descriptive study that used both quantitative and qualitative data. The use of these two types of data was intended to provide a more comprehensive picture of the learning conditions and the need for physics instructional media on the topic of thermodynamics. The study was conducted at a public high school in Jakarta during the ongoing semester. The participants consisted of 51 Grade 11 students and one physics

teacher. Participants were selected purposively because they were directly involved in learning thermodynamics and were considered capable of providing information relevant to the objectives of the study (Palinkas dkk., 2015)

Data was collected using four instruments: a questionnaire, an interview guide, an observation sheet, and a document-review guide. The questionnaire was administered to students to obtain data on their learning interest, learning-style preferences, use of instructional media, and difficulties in understanding thermodynamics. Semi-structured interviews were conducted with one physics teacher and three student representatives to explore their learning experiences, conceptual difficulties, and needs for digital and contextual instructional media in great depth. Direct observations were conducted during the learning process to examine the teacher's instructional strategies, student engagement, and use of instructional media in the classroom. A review of the instructional materials used at the school was conducted to assess their content, material structure, visual presentation, and forms of learning assessment. Source and method triangulation were used to enhance the validity of the findings by comparing data from various instruments and sources (Creswell & Creswell, 2018)

Instrument validation was conducted through expert judgment by a validator with expertise in physics education and instructional-material development. The validation covered the alignment of the content with the research objectives, language clarity, measurability of the indicators, and instrument relevance. The validator's suggestions were used to revise the instruments before data collection. The validity of the qualitative data was

strengthened through source and method triangulation by comparing data from the teacher, students, observations, and document reviews.

Quantitative data from the questionnaire were analyzed descriptively using percentages to describe the tendencies of students' responses for each indicator. Meanwhile, qualitative data obtained through interviews, observations, and document reviews were analyzed using the interactive analysis model of Miles, Huberman, and Saldaña, which comprises data reduction, data display, and conclusion drawing or verification (Miles dkk., 2014). The results of all analyses were used to identify the need for physics instructional media on Grade 11 thermodynamics and to reinforce the urgency of developing digital and contextual instructional materials.

RESULT AND DISCUSSION

Based on data obtained from surveys, classroom observations, in-depth interviews, and document reviews, this section presents field findings on physics learning conditions, the quality of instructional materials, the need for digital media, and students' views of more contextual learning approaches. These findings are discussed under five main themes to map the gap between actual school conditions and the ideal requirements for improving students' science literacy. This analysis provides an in-depth overview of the challenges faced by teachers and students while serving as a foundation for formulating more relevant instructional-material solutions.

a. Physics Learning Conditions

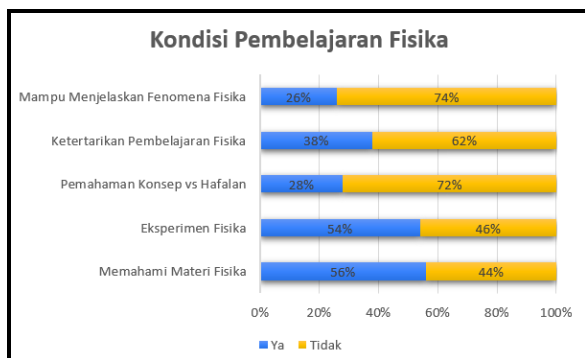


Figure 1. Survey Results on Physics Learning Conditions

BASED ON THE QUESTIONNAIRE COMPLETED BY 51 students, responses regarding physics learning conditions revealed several specific findings. More than half of the students (56%) stated that they found it easy to understand physics concepts. Regarding classroom activities, more than half (54%) also reported that they frequently participated in experiments. However, more than one-third of the students (38%) still considered physics learning uninteresting. In terms of learning methods, more than one-quarter (28%) admitted that they more often memorized formulas than understood concepts, while approximately one-quarter (26%) experienced difficulty explaining physics phenomena in real-life contexts.

These findings indicate that the physics instruction provided has helped some students understand the material; however, it has not fully developed their ability to connect physics concepts with phenomena encountered in everyday life. This condition is evident in the number of students who still rely on formula memorization and experience difficulty when asked to explain physics phenomena scientifically. In other words, students' understanding tends to remain at the level of basic conceptual mastery and has not yet fully developed into the ability to apply concepts in real-life contexts.

This disparity stems from the way learning is conducted. Classroom observations at a public high school in Jakarta showed that instruction was dominated by lecture-based methods. In thermodynamics lessons, abstract concepts were primarily delivered through verbal explanations and PowerPoint presentations. Consequently, students had limited learning experiences that enabled them to directly observe the relationship between physics concepts and phenomena occurring in their surrounding environment.

This is consistent with the teacher's statement during the interview:

"Actually, if I rely only on lectures as I do, students will certainly have difficulty visualizing the concepts. What exactly is thermodynamics? The concepts are abstract, and they cannot see them directly."

This statement shows that the teacher recognizes the limitations of lecture-based methods in helping students understand abstract thermodynamics concepts. Therefore, the proposed instructional material is designed as an interactive digital resource that presents concepts through multiple representations, including text, images, diagrams, animations, simulations, and data visualizations. It also incorporates contextual phenomena from everyday life, technology, and the environment as starting points for learning, followed by investigative activities, data processing, and guiding questions. These features are expected to help students gradually develop conceptual understanding, connect thermodynamic equations with their physical meaning, and reduce their reliance on formula memorization and verbal explanations alone.

Students also confirmed that without illustrations or hands-on practice, they have difficulty understanding the derivation and

origins of physics equations. This finding is consistent with the instructional-material review, which showed that the material is generally presented directly from definitions to final formulas without beginning with phenomena that could arouse students' curiosity or encourage them to conduct simple investigations.

Overall, the dominance of lecture-based methods and static media in teaching abstract topics indicates that physics instruction still needs to be supported by instructional materials that facilitate more active, contextual, and investigative learning activities. Such materials are expected to help students develop conceptual understanding through observing phenomena, analyzing data, and gradually discovering concepts.

This condition is consistent with the direction of other studies emphasizing the need for more interactive digital instructional materials. The development of interactive e-modules on heat and thermodynamics (Utamy & Hufri, 2024) and interactive electronic student worksheets on the laws of thermodynamics (Annisa Wudda dkk., 2024) indicates that digital instructional materials are considered relevant for supporting physics learning in schools. Although both studies focused primarily on product validity and feasibility rather than their impact on student competencies, the needs identified in the present study specifically point to instructional materials that not only present concepts but also facilitate a learning sequence involving phenomena, investigations, data representation, graph interpretation, and mathematical modeling.

b. Physics Instructional Material Conditions

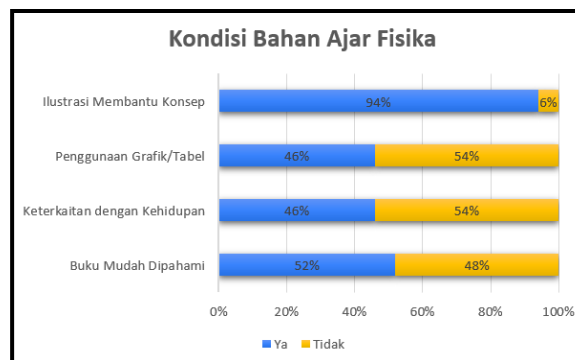


Figure 2. Survey Results on Physics Instructional Material Conditions

The questionnaire data showed students' evaluations of the instructional materials used. More than half of the students (52%) felt that their physics textbooks were easy to understand. However, nearly half (46%) stated that the textbooks rarely connected the material to everyday life, while the same proportion (46%) felt that information was rarely presented in the form of graphs or tables. As a visual aid, nearly all students (94%) reported that illustrations or images in textbooks greatly helped them understand concepts. This percentage indicates students' strong need for visual representations of the material. However, observations during thermodynamics lessons showed that the school textbook was rarely used, and students relied more heavily on presentation materials prepared by the teacher.

These findings indicate that the ease of understanding instructional materials does not necessarily mean that they optimally meet students' learning needs. Students need not only materials that are easy to read but also concept presentations that help them connect physics theory with real-world phenomena. The limited connection between the material and everyday life, along with the minimal presentation of data in graphs and tables, indicates that the instructional materials used

do not yet fully support contextual, science-literacy-based learning.

The high need for visualization was directly confirmed by students during interviews about their learning preferences:

“Personally, I need illustrations. I learn better when there are some illustrations for example, showing what is being pressed or what is being pulled because I need to see the pictures.”

The importance of visualization was reinforced by the convergence of questionnaires, observation, and interview data. The questionnaire data indicated students' need for more visual and comprehensible presentations of the material. Observations showed that instruction was still dominated by verbal explanations and the use of formulas, while the use of images, diagrams, animations, and simulations remained limited. These findings were consistent with interviews with the teacher and students, which revealed that thermodynamics concepts particularly microscopic processes and relationships among variables were difficult to understand when presented solely through text and mathematical equations. Therefore, the instructional materials developed should include dynamic visualizations, diagrams illustrating relationships among variables, simulations, and guiding questions to help students connect microscopic, macroscopic, and mathematical representations. The convergence of these findings confirms that visualization is not merely a supplement but a core component of instructional materials for developing conceptual understanding of thermodynamics.

During the interview, the teacher also stated that the existing instructional materials were less effective in presenting contextual phenomena visually. As a result, students

experienced difficulty reading thermodynamic graphs without direct explanations from the teacher. This finding was reinforced by the instructional-material review, which showed that the images presented were mostly illustrative and had not yet functioned as tools for conceptual analysis or data interpretation.

Overall, the instructional materials currently used have not been able to facilitate students' understanding of concepts through multiple representations, particularly graphs and visualizations of phenomena. Therefore, instructional materials are needed that not only present information in textual form but also include illustrations, graphs, and data-interpretation activities to help students develop a more comprehensive conceptual understanding.

The need for visual- and graph-based instructional materials is consistent with research on multiple-representation learning in physics, which shows that using various representations, such as images, graphs, and diagrams, can help students understand abstract concepts. Therefore, future instructional-material development should ensure that visual elements function not merely as aesthetic supplements but as cognitive tools that help students interpret physics concepts and data more meaningfully.

c. Digital Media and Instructional Material Needs

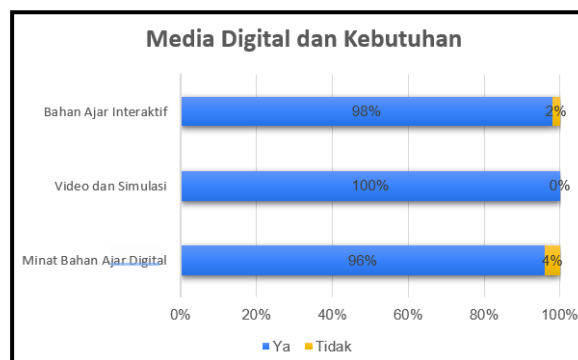


Figure 3. Survey Results on Digital Media and Instructional Material Needs

Students demonstrated a very strong need for the use of digital media in physics learning. The survey results showed that nearly all students (96%) were interested in learning with digital instructional materials accessible via mobile phones. Moreover, all respondents (100%) agreed that they found it easier to understand the material when supported by audio, video, or interactive simulations. Similarly, nearly all students (98%) stated that they needed instructional materials that were interactive and engaging. These findings indicate that students not only desire more flexible access to learning but also seek a more visual and interactive learning experience than the conventional instruction they have received.

Students' strong interest in digital instructional materials indicates that technology has become an inseparable part of their learning activities. Therefore, the use of digital instructional materials has the potential to increase student engagement in the learning process, particularly when teaching abstract physics topics that require visualization to facilitate conceptual understanding.

This need is consistent with statements made by the teacher and students during the interviews. Both parties agreed that limited physical facilities make digital simulations a highly relevant alternative for physics learning. The teacher explained that the available laboratory facilities do not yet fully support experiment-based learning optimally.

This was emphasized by the teacher, who felt constrained by the school's limited laboratory facilities:

"The materials and equipment in our laboratory are also quite outdated. Therefore, we need instructional media, particularly representative simulations or videos, to explain the concepts to students."

This statement indicates that the need for digital media comes not only from students as users but also from teachers as learning facilitators. Virtual simulations and instructional videos are considered capable of helping explain concepts that are difficult to observe directly, while also serving as alternatives when practical activities are constrained by limited facilities and infrastructure.

However, observations showed that no interactive media were used during instruction to support students' visual understanding of concepts. Students' use of mobile phones was limited to searching for information when instructed by the teacher. The instructional-material review also showed that the learning resources were still text-based and lacked links to virtual simulations, instructional videos, or other interactive activities. These findings indicate a gap between students' need for digital learning and the current classroom learning conditions..

Overall, students' strong interest in digital media, which is not matched by the availability of interactive instructional materials, highlights the need to develop materials that make more effective use of technology. Such materials should function not only as sources of information but also as tools for facilitating concept exploration, phenomenon visualization, and independent learning activities.

The need for smartphone-based digital instructional materials is consistent with the development of an Android-based virtual laboratory e-module for Grade 11 thermodynamics, which was considered highly feasible and received positive responses from students (Saepulloh dkk., 2022). In addition, the use of smartphones to access and process experimental data was demonstrated in the development of an

Internet of Things (IoT)-based thermodynamics experimental medium, which enabled students to interact directly with observational data (Liana dkk., 2020). Although the products developed differed in form, both studies indicate that thermodynamics learning can be designed to be more interactive, contextual, and data-based by utilizing devices that students are already familiar with in their daily lives.

Based on these findings, the development of I-SETS-based digital instructional materials should utilize interactive features such as videos, virtual simulations, data visualizations, and exploratory activities accessible via smartphones. These features are expected to help students understand thermodynamics concepts more concretely while supporting the development of science literacy through observation, data interpretation, and problem-solving activities.

d. The Need for Learning That Connects Islamic Values, Society, Technology, the Environment, and Everyday Life

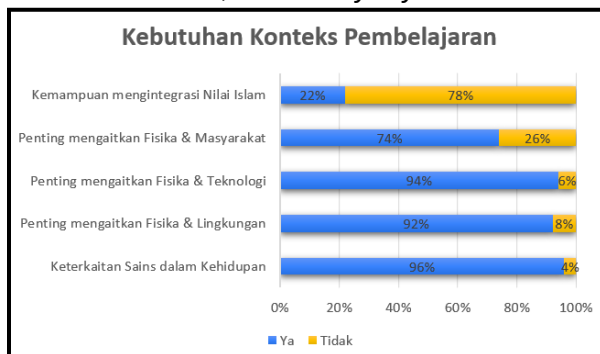


Figure 4. Survey Results on the Need for Contextualized Learning

Students' responses to the multidimensional approach varied. In the science dimension, nearly all students (96%) wanted to understand the relationship between science and everyday life. Regarding technology and the environment, most students (94%) were more interested when

physics was connected to technology, while nearly all students (92%) expressed interest in environmental issues. Conversely, nearly three-quarters of the students (74%) were not interested in connecting physics with social life. In the religious dimension, more than three-quarters of the students (78%) stated that they were not yet able to relate physics learning to Islamic values.

These findings indicate that students have a strong preference for contextualized physics learning. Students find it easier to see the connections between physics and technology, the environment, and everyday life because they encounter these three aspects more frequently in their daily experiences. Conversely, their limited ability to relate physics to Islamic values suggests that they have not yet had learning experiences that explicitly address the relationship between scientific concepts and religious values.

The high percentage of students who were unable to connect science and religion is closely related to the learning process in the classroom. During the interview, the teacher stated that the integration of Islamic values had not been implemented optimally due to concerns about accurately presenting religious content.

The teacher expressed this concern directly:

"Regarding Islamic values, honestly, I have limitations because I am afraid of making a mistake. My understanding of Islam may not be as strong as that of colleagues who studied at an Islamic university. Although some concepts can be related to Islam, I still feel uncertain or hesitant."

This statement indicates that the limited integration of Islamic aspects into learning is not due to a lack of willingness on the teacher's part but rather to limited references

and concerns about the validity of the material presented. Consequently, students do not have sufficient opportunities to understand the relationship between physics concepts and Islamic values.

Classroom observations of thermodynamics lessons also showed that the context used by the teacher were still limited to technological aspects, such as steam engines, while environmental issues, society, and religious values were rarely discussed. This finding was reinforced by the instructional-material review, which revealed no discussion of energy issues, the environmental impacts of technology use, or Islamic reflections related to thermodynamics concepts.

Overall, these findings indicate a need for instructional materials that systematically integrate Islamic, environmental, technological, and social aspects. Such integration is important so that students not only understand physics concepts theoretically but also recognize their relevance to real life and develop scientific and spiritual awareness in balance.

As supported by previous research, I-SETS-based thermodynamics instructional media have been developed through Powtoon-assisted instructional videos and were deemed feasible by validators, teachers, and students (Dewi et al., 2023). Therefore, the present study needs to develop a more comprehensive integration by incorporating technological, environmental, and social contexts into learning activities, while also including an Islamic dimension that has undergone expert validation.

e. Science Literacy Skills

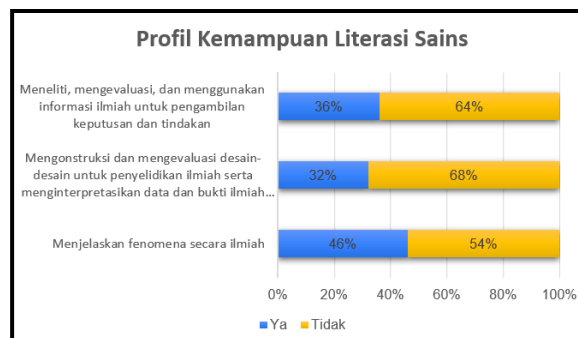


FIGURE 5. SURVEY RESULTS ON STUDENTS' SCIENCE Literacy Skills

The profile of students' science literacy skills indicates that most students still experience difficulties with various measured science literacy competencies. Based on the questionnaire results, more than half of the students (54%) were unable to explain phenomena scientifically using physics concepts. Regarding the indicators of constructing and evaluating scientific investigation designs and interpreting scientific data and evidence, more than two-thirds of the students (68%) stated that they were unable to perform these skills. In addition, nearly two-thirds of the students (64%) were also unable to research, evaluate, and use scientific information as a basis for decision-making and action.

These findings indicate that students' science literacy skills still need to be improved, particularly in data interpretation, evaluation of scientific evidence, and the application of physics concepts in real-life contexts. This suggests that the learning process has not yet fully provided experiences that train students to use scientific knowledge to understand phenomena, analyze information, and make decisions based on scientific evidence. Science literacy is not limited to conceptual mastery; it also involves the ability to apply knowledge to solve problems encountered in everyday life.

The lowest-achieving indicators were the abilities to construct and evaluate

scientific investigations and to interpret scientific data and evidence. These results show that most students still experience difficulty reading, analyzing, and drawing conclusions from available data. This limited ability indicates that the learning process has not provided students with sufficient opportunities to actively engage with scientific data and evidence. Consequently, students are more accustomed to receiving concepts and formulas directly than to developing understanding through investigation and analysis.

These findings were reinforced by observations of thermodynamics lessons. When the teacher discussed pressure–volume (P – V) graphs, several students had difficulty relating the graph's shape to the underlying concepts. Some students also confused isothermal and isobaric processes and struggled to explain the physical meaning of the changes represented in the graph. This condition indicates that students are not yet accustomed to using scientific representations as a basis for understanding physical phenomena.

These difficulties are consistent with the results of the student interviews. One student stated:

“In my opinion, without an explanation from Mr. R, I probably would not be able to understand it. When the formulas are first introduced, I also get confused about how they were derived and how they came about.”

This statement indicates that some students still depend on the teacher's explanations to understand the relationships among phenomena, data, and mathematical models. Students tend to view formulas as information to be used for solving problems rather than as mathematical representations of phenomena that can be explained through

observation and scientific evidence. This dependence suggests that students' scientific reasoning and data interpretation skills have not yet developed optimally.

The low level of science literacy identified in this study appears to be related to the learning conditions and instructional materials previously described. The dominance of lecture-based methods, limited use of interactive media, minimal presentation of data in graphs or tables, and insufficient connection between physics concepts and everyday phenomena have restricted students' opportunities to develop scientific thinking skills. Consequently, students are more accustomed to memorizing concepts and formulas than to using them to explain phenomena, evaluate information, or solve contextual problems.

These findings also indicate a relationship between low science literacy and students' need for more contextualized learning. The previous section showed that nearly all students wanted physics learning to be connected to everyday life, technology, and the environment. This need suggests that students require learning experiences that enable them to recognize the relevance of physics concepts in various real-life situations. Therefore, improving science literacy cannot be achieved through the delivery of concepts alone; it must be supported by learning that presents contextual phenomena as the starting point of instruction.

The findings of this study are consistent with previous research that has attempted to incorporate science literacy into thermodynamics instructional materials (Huda dkk., 2022) and to develop science literacy skills through a temperature heat module (Fadilah dkk., 2022). However, both studies focused primarily on product validation and did not present operational, performance-

based tests of improvements in students' science literacy competencies. In contrast, a study developing thermodynamics experimental media demonstrated effectiveness in improving learning outcomes and included data-based scientific work closely related to science literacy competencies, although these were not explicitly identified as PISA competencies (Iliana et al., 2020). This further underscores the need for instructional-material designs that place visual literacy activities and data interpretation at the core of learning.

Overall, the findings on students' science literacy profiles reinforce the urgency of developing digital and contextualized physics instructional materials. Digital materials enable the presentation of diverse simulations, visualizations, and data representations, while the contextual approach helps students connect physics concepts with everyday life, technology, the environment, and various phenomena they encounter. Thus, the developed instructional materials are expected not only to support conceptual understanding but also to serve as a means of developing students' science literacy skills in a more meaningful way.

CONCLUSION

The findings of this needs analysis study demonstrate the urgency of developing instructional materials that can address the limitations of physics learning in schools. The dominance of lecture-based methods and static instructional media has caused students to rely more on formula memorization than on deep conceptual understanding. Therefore, a transformation in instructional materials is needed to facilitate active learning activities, ranging from observing real-world phenomena and conducting independent investigations to analyzing data.

Furthermore, these findings emphasize the importance of improving the quality of visualizations, such as graphs and illustrations, so that they function as cognitive tools that support students' thinking processes rather than merely serving as aesthetic supplements. The use of smartphone-based virtual simulations also offers a strategic solution for addressing limitations in school laboratory facilities. Moreover, to meet the need for more holistic learning, instructional-material development should systematically integrate physics with technology, the environment, and Islamic values, thereby providing clear guidance for teachers during the learning process.

Based on these findings, it is recommended that digital instructional media be developed specifically to improve science literacy, namely an I-SETS-based digital module (Islamic Science, Environment, Technology, and Society). This module is expected not only to present material interactively but also to integrate spiritual, social, and environmental dimensions into physics concepts. Through this comprehensive instructional media, students are expected to achieve a more holistic conceptual understanding and develop competitive science literacy skills to face future challenges.

DAFTAR PUSTAKA

- Amini, S., & Sinaga, P. (2021). Inventory of scientific literacy ability of junior high school students based on the evaluation of PISA framework competency criteria. *Journal of Physics: Conference Series*, 2596(1), 012073. <https://doi.org/10.1088/1742-6596/1806/1/012017>

- Annisa Wudda, A., Hufri, H., Gusnendi, G., & Satria Dewi, W. (2024). Validasi E-LKPD Interaktif Berbasis Model Pembelajaran Contextual Teaching and Learning pada Materi Hukum Termodinamika. *Jurnal Pendidikan Tambusai*, 8(1), 7543–7552. <https://doi.org/10.31004/jptam.v8i1.13533>
- Aprianti, R., Ambarwulan, D., & Purwahida, R. (2023). Improving high school students' conceptual knowledge using contextual E-Module on optical devices topic. *Journal of Physics: Conference Series*, 2596(1), 012073. <https://doi.org/10.1088/1742-6596/2596/1/012073>
- Besche-Truthe, F., & Seitzer, H. (2025). Testing for the money: An analysis on the interdependence of participation in international large-scale assessments and development aid networks. *Frontiers in Education*, 10, 1429107. <https://doi.org/10.3389/feduc.2025.1429107>
- Costa, A. M., Ferreira, M. E., & Loureiro, M. J. da S. (2021). Scientific literacy: The conceptual framework prevailing over the first decade of the twenty-first century. *Revista Colombiana de Educación*, (81), 195–228. <https://doi.org/10.17227/rce.num81-10293>
- Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications, Inc.
- Das, K., Agarwal, V., Lath, V., & Wibowo, P. (2019). *Automation and the Future of Work in Indonesia*. McKinsey & Company.
- Dewi, N. A., Nasbey, H., & Umiatin, U. (2023). PENGEMBANGAN VIDEO PEMBELAJARAN BERBASIS I-SETS BERBANTUAN POWTOON PADA MATERI TERMODINAMIKA KELAS XI. *SEMINAR NASIONAL FISIKA 2016 UNJ*. <https://doi.org/10.21009/03.1102.PF45>
- Elhai, J. (2023). Science Literacy: A More Fundamental Meaning. *Journal of Microbiology & Biology Education*, 24(1). <https://doi.org/10.1128/jmbe.00212-22>
- Fadilah, H., Hamdani, D., & Purwanto, A. (2022). PENGEMBANGAN MODUL SUHU DAN KALOR DENGAN PENDEKATAN SAINTIFIK UNTUK MELATIHKAN LITERASI SAINS PESERTA DIDIK DI SMA. *Jurnal Kumparan Fisika*, 4(3), 185–192. <https://doi.org/10.33369/jkf.4.3.185-192>
- Hijriati, Sahyar, & Derlina. (2021). The Development of Physics Test Instrument Based on PISA for Optical Topic in High School. *Journal of Physics: Conference Series*, 1811(1), 012039. <https://doi.org/10.1088/1742-6596/1811/1/012039>
- Huda, C., Karimah, L., & Kurniawan, W. (2022). Pengembangan Bahan Ajar Fisika Berbasis Kontekstual dengan Memasukan Literasi Sains pada Materi Termodinamika Kelas XI Siswa SMA/MA. *Lontar Physics Today*, 1(2), 103–112. <https://doi.org/10.26877/lpt.v1i2.12019>

- Liana, Y. R., Linuwih, S., & Sulhadi, S. (2020). The Development of Thermodynamics Law Experiment Media Based on IoT: Laboratory Activities Through Science Problem Solving for Gifted Young Scientists. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 6(1), 51–64. <https://doi.org/10.21009/1.06106>
- Malgieri, M., Onorato, P., & Valentini, A. (2016). Improving the Connection Between the Microscopic and Macroscopic Approaches to Thermodynamics in High School. *Physics Education*, 51(6). <https://doi.org/10.1088/0031-9120/51/6/065010>
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook*. SAGE Publications, Inc.
- Muliyani, R., Suhandi, A., & Prima, E. C. (2023). Investigating Strategies and Best Practices in Teaching Heat and Temperature: A Systematic Review in Science and Physics Education. *Jurnal Penelitian Pendidikan IPA*, 9(7), 263–269. <https://doi.org/10.29303/jppipa.v9i7.4328>
- Nilyani, K., Anjani, H. R., Desnita, D., & Usmeldi, U. (2023). Needs Analysis to Develop Physics Learning E-Modules on Static Electricity Material. *JURNAL EKSakta Pendidikan (JEP)*, 7(2), 289–300. <https://doi.org/10.24036/jep/vol7-iss2/781>
- OECD. (2023). *PISA 2022 Assessment and Analytical Framework*. OECD Publishing. <https://doi.org/10.1787/dfe0bf9c-en>
- Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Administration and Policy in Mental Health and Mental Health Services Research*, 42(5), 533–544. <https://doi.org/10.1007/s10488-013-0528-y>
- Saepulloh, D., Gunawan, I., & Agustin, S. A. (2022). Android-Based Virtual Laboratory Development (Case Study Of Class Xi Of Sma In Bandar Lampung). *Asia Information System Journal*, 1(1), 27. <https://doi.org/10.24042/aisj.v1i1.13625>
- Santoso, A. N., Sunarti, T., & Wasis, W. (2023). Effectiveness of Contextual Phenomena-Based Learning to Improve Science Literacy. *International Journal of Current Educational Research*, 2(1), 17–26. <https://doi.org/10.53621/ijocer.v2i1.205>
- Utamy, D. M., & Hufri, H. (2024). Validasi E-Modul Interaktif Berbasis Saintifik pada Materi Kalor dan Termodinamika. *Jurnal Pendidikan Tambusai*, 8(2). <https://doi.org/10.31004/jptam.v8i2.17248>