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Needs Analysis for the Design of STEM-Based Electronic Worksheets to Facilitate Students' Science Literacy in Thermodynamics

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Abstract. Physics education requires the development of teaching materials capable of fostering students' science literacy, particularly in the abstract and complex subject of thermodynamics. This study developed a STEM-based electronic student worksheet (E-LKPD) design using Liveworksheet to provide interactive and contextual learning at SMAN 2 Padang Panjang. The research method employed a Research and Development (R&D) approach, which included needs analysis, identification of student characteristics, and teacher interviews as initial data. Science literacy test results showed that the average student scores for the indicators "explaining phenomena scientifically" were 46%, "designing and evaluating investigations" were 51%, and "researching, evaluating, and using scientific information for decision-making" were 12%, all of which were classified as very low. An analysis of student characteristics revealed varying levels of interest and motivation to learn, while the available instructional materials consisted primarily of text-based worksheets and routine exercises that did not sufficiently support exploration, concept development, and active student engagement. These conditions highlight the need for instructional materials that are more adaptive, activity-rich, and contextual. The STEM-based electronic student worksheet design is viewed as a relevant and interactive teaching material capable of integrating conceptual, procedural, and reflective activities, as well as implicitly facilitating students' comprehensive science literacy, helping them connect thermodynamics concepts to real-world phenomena, and enhancing a more meaningful learning experience.

Keywords: Science literacy, Thermodynamics, Electronic student worksheet, STEM, Liveworksheet

1. Introduction

Education plays a vital role in preparing human resources capable of keeping pace with advancements in science and technology in the 21st century (Nofrida & Najib, 2023). Advances in digital technology require the education sector to continuously innovate in learning, particularly through the use of technology that supports a more active, flexible, and learner-centered learning process (Ambarwati et al., 2022). The use of technology in learning can help students access information, understand concepts more easily, and connect the material to real-life situations in their daily lives. Technology not only serves as a learning aid but also to foster a more active, contextual, and relevant learning process. Strengthening technology-based learning is a crucial component in fostering 21st-century skills, as 21st-century learning is required to be technology-based so that students become accustomed to life skills aligned with the demands of the times (Rosnaeni, 2021). The targeted application of technology in learning is necessary to develop students who are adaptable, critical thinkers, and capable of navigating change in the digital age.

The 21st-century skills that students need to possess are known as the 4Cs: critical thinking, creativity, collaboration, and communication (Putri & Mufit, 2023). These skills are crucial because students are expected to think critically, generate new ideas, collaborate, and communicate their ideas clearly—all of which are essential components of the 4C skills required to meet the demands of 21st-century learning (A. K. Sari & Trisnawati, 2019). In physics education, the 4C skills can be developed through learning processes that encourage students to actively conduct investigations, engage in discussions, collaborate, and solve problems scientifically (Utama & Festiyed, 2020). Instruction must be designed not only to emphasize conceptual mastery but also to provide opportunities for students to develop their ability to think and communicate scientifically. The development of these 21st-century skills is closely linked to science literacy, as students also need to be able to understand, use, and apply scientific knowledge in their daily lives.

PISA (PISA, 2025) defines scientific literacy as students' ability to contribute as citizens by considering scientific concepts and phenomena, evaluating research methods, interpreting data and evidence, and using scientific information to make decisions. Irsan (Irsan, 2021) explains that science literacy is not only related to conceptual understanding but also to the ability to use scientific knowledge to identify problems, evaluate information, draw conclusions based on evidence, and solve problems in everyday life. Irsan (Irsan, 2021) states that scientific competence encompasses the ability to think scientifically, evaluate scientific information, and use evidence in research to identify problems, evaluate information, and draw conclusions based on evidence. In science education, scientific competence refers to more than just conceptual understanding. Rahayuni et al. (Rahayuni et al., 2016) support this idea, demonstrating that there is a relationship between critical thinking skills and scientific competence. They also show that students' inability to think critically can be linked to a lack of scientific competence. Since students are taught to analyze data, evaluate information, and make decisions based on evidence, Sanjiartha et al. (Sanjiartha et al., 2024) argue that scientific competence is crucial for fostering a generation of critical thinkers and innovators. Science education must be taught in a more engaging, context-based, and problem-solving-focused manner. Previous research findings indicate that Indonesian students still exhibit weaknesses in their scientific competence.

Within the framework proposed by PISA (PISA, 2025), science literacy encompasses the ability to explain phenomena scientifically, design and evaluate scientific investigations, and interpret scientific data and information for decision-making. These competencies require students to be able to integrate various concepts in solving real-world problems (Muttaqiin, 2022). Problem-solving, inquiry-based activities, and the application of concepts in daily life must be components of a learning approach that fosters the development of these competencies (Barokah et al., 2024). However, a more active, context-based, and problem-solving-focused approach to science education is needed, as research indicates that Indonesian students have low levels of science literacy. Results from the Programme for International Student Assessment (PISA) show that Indonesian students still struggle to understand scientific concepts and relate them to daily life (PISA, 2022). These results highlight just how low Indonesian students' science literacy is. In addition, students demonstrate difficulty interpreting data and critically evaluating scientific information (Yuliati, 2017). This situation indicates that current teaching methods do not fully support students' science literacy (Rubini et al., 2016). Students' inability to think scientifically and solve problems in daily life may be caused by a lack of science literacy.

Students’ low science literacy may be caused by a teaching approach that is still insufficiently contextual, so that students are not yet accustomed to connecting scientific concepts with real-world phenomena in their daily lives (Yusmar & Fadilah, 2023). In addition, the use of inappropriate textbooks or teaching materials is also a contributing factor because the content does not fully encourage students to conduct investigations, reason from evidence, and solve problems scientifically (Suparya et al., 2022). Science literacy is also influenced by students’ learning styles and reading habits; thus, instructional materials that do not align with students’ learning characteristics can hinder their understanding of scientific information (W. Sari, 2021). Other factors contributing to low science literacy include students’ misconceptions, teachers’ limited mastery of science literacy, and insufficient school facilities and infrastructure (Yusmar & Fadilah, 2023). Students’ science literacy may be low if instruction is not active, instructional materials are irrelevant, learning resources are limited, and the learning environment does not support students’ scientific thinking processes.

There are many ways to improve students’ scientific abilities, but the STEM approach is the most appropriate because it integrates science, technology, engineering, and mathematics into the learning process and connects them to real-world problem-solving. According to Afriana et al. (Afriana et al., 2016), project-based learning integrated with STEM can enhance students’ scientific competencies, both in terms of knowledge and skills. It can also boost students’ motivation and enjoyment, creating a pleasant learning experience. Furthermore, Sakti and Defianti (Sakti & Defianti, 2022) ote that STEM education does not merely focus on knowledge transfer; it also teaches students critical thinking, problem-solving, scientific inquiry, and the formulation of data-driven explanations. Furthermore, according to a meta-analysis by Irpan et al. (Irpan et al., 2022) the STEM approach improves students’ scientific abilities in science and physics. Consequently, the implementation of STEM requires high-quality instructional materials. Sakti and Defianti (Sakti & Defianti, 2022) emphasize that to enhance students’ scientific abilities, it is necessary to develop STEM-based instructional materials or textbooks.

One type of instructional material that can support the implementation of STEM in physics education is the electronic student worksheet (Fasita et al., 2024). STEM-based electronic student worksheets can help students improve their critical thinking skills by engaging in learning activities focused on problem-solving and the application of scientific concepts (Salsabilla et al., 2024). Electronic student worksheet are digital learning materials designed to enable students to learn independently and interactively using electronic devices (Utami et al., 2024). The use of electronic student worksheet can make student more engaged in learning, as these worksheets incorporate various interactive media such as images, videos, animations, and practice questions (Shalahuddin & Hayuhantika, 2022). Furthermore, electronic worksheets can help make the learning process more flexible and tailored to the needs of each student in today’s digital age (Wati & Istiqomah, 2019). To ensure that electronic student worksheet can be used more interactively and remain easily accessible to students, a platform capable of effectively supporting digital learning is required.

Liveworksheet is one of many platforms available for teachers to create interactive electronic worksheets for their students (Daryanto et al., 2022). This web-based platform allows teachers to transform conventional worksheets into interactive digital worksheets that can be accessed online (Nurlaila et al., 2022). Interactive multiple-choice questions, drag-and-drop activities, audio and video content, and automatic grading are some of the platform’s features that provide immediate feedback to students (Asiri, 2022). Using Liveworksheet in the classroom can boost student engagement and help educators better manage learning assessments (Daryanto et al., 2022). Digital platforms like Liveworksheet are also ideal for teaching physics, a subject that relies on interaction and visualization to help students understand abstract concepts. Liveworksheet offers visual and auditory features as well as interactive activities that can help tailor instruction to students' various learning styles.

Students' learning styles also need to be considered in the learning process because each student has a different way of receiving, processing, and understanding information—whether through visual, auditory, or kinesthetic means. Yulianci et al. (Yulianci et al., 2020) show that students in physics learning tend to have diverse learning styles, so teachers need to recognize students' learning characteristics so that instruction can better align with their needs. Kadir et al. (Kadir et al., n.d.) It also found that visual, auditory, and kinesthetic learning styles influence students' physics learning outcomes; thus, aligning teaching strategies and instructional materials with these learning styles can help improve students' understanding. Furthermore, Devy et al. (Devy et al., 2022) explain that students' learning styles and thinking styles are related to their level of understanding of physics concepts, especially when students must grasp concepts that cannot always be directly observed. Therefore, physics instruction requires instructional materials and learning activities capable of accommodating the diversity of students' learning styles so that abstract concepts can be understood more easily.

In physics education, one of the topics that requires visualization and a solid conceptual understanding is thermodynamics (Nasution, 2024). Students often find thermodynamics challenging because it involves abstract concepts and relies heavily on mathematical equations (Mufit & Fauzan, 2019). Students often struggle to understand the laws of thermodynamics and relate them to phenomena in everyday life (Abdullah, 2016). Thermodynamics instruction also still heavily emphasizes the use of formulas, so students tend to memorize them without deeply understanding the concepts (Nasution, 2024). These conditions highlight the need for interactive instructional materials that can help students understand thermodynamic concepts in a more contextual way and support the development of their science literacy.

Based on these various issues, there is a need to develop instructional materials that can support physics learning that is more interactive, contextual, and oriented toward the development of students' science literacy (Utami et al., 2024). The development of STEM-based electronic student worksheet s using Liveworksheet for thermodynamics material can serve as an alternative solution to address these needs (Wahyuniyati et al., 2025). The integration of STEM into electronic student worksheets is expected to help students understand concepts through problem-solving activities and scientific inquiry (PISA, 2025). The use of Liveworksheet can also increase student engagement through interactive learning features and immediate feedback during the learning process (Utami et al., 2024). Therefore, a STEM-based electronic student worksheet design is needed to support and facilitate students' science literacy in thermodynamics.

2. Method

The development of the STEM-integrated electronic worksheets follows the Research and Development (R&D) approach and the four stages of the 4-D model: Define, Design, Develop, and Disseminate. This process aims to create learning materials that are valid, practical, and responsive to students' learning requirements (Thiagarajan et al., 1974). The 4-D model supports the systematic development of teaching materials through needs analysis, design, product development, and evaluation of validity and practicality prior to classroom implementation (Fitria et al., 2025). This approach enables the creation of interactive and practical teaching materials tailored to students' characteristics and promotes the improvement of science literacy.

This study is a descriptive study conducted at the needs analysis stage for the development of STEM-based electronic student worksheet using Liveworksheet on thermodynamics material. The study was conducted at SMAN 2 Padang Panjang. Data were collected through teacher interviews, student characteristic questionnaires, and initial science literacy tests. The study participants consisted of one physics teacher and students enrolled in physics classes at the study school. All students in the class serving as the study site were included as the sample using total sampling. A total of 30 students took the initial science literacy assessment and completed the student characteristics questionnaire.

The research instruments included a teacher interview guide, a student characteristics questionnaire, and a science literacy baseline test. The teacher interview guide consisted of 30 questions covering physics learning conditions, the use of teaching materials and stundent worksheets, the use of technology, the application of STEM, science literacy, and the need for the development of electronic student worksheets. The student characteristics questionnaire consisted of 45 statements covering background, interests, motivation, learning styles, digital learning, and science literacy. A five-point Likert format was applied to score the questionnaire, where higher values represented stronger agreement and lower values indicated stronger disagreement. Students' initial proficiency was examined through six contextual essay tasks related to thermodynamics, covering scientific explanation, investigation design and evaluation, and the interpretation of data and evidence.

Data collection was conducted by interviewing physics teachers regarding learning conditions and instructional material needs. Subsequently, students completed a demographic questionnaire and took the pre-test for 90 minutes. Participant identities were kept confidential, and the data were used solely for research purposes. Interview data were analyzed descriptively through the stages of data reduction, grouping responses by theme, and drawing conclusions. Questionnaire data were analyzed using weighted scores, averages, and percentages for each dimension. Test data were analyzed by summing the scores for each indicator, converting them to percentages, and grouping them based on predetermined proficiency categories. The results of the interviews, questionnaires, and tests were then compared to obtain a more comprehensive picture of the students' characteristics, initial science literacy proficiency, and the need for the development of STEM-based electronic student worksheets.

The average science literacy test scores of the students were then analyzed and classified into science literacy level categories in Table 1.

Table 1. Science Literacy Assessment Criteria

Score %	Category
81-100	Very High
76-80	Height
60-75	Enough
55-59	Low
≤ 54	Very low

(Source: (Purwanto, 2010)

3. Results and Discussion

A preliminary study was conducted to obtain a comprehensive overview of the state of physics learning in the Thermodynamics unit at SMAN 2 Padang Panjang. Research data were collected through an initial science literacy test, an analysis of student characteristics, and interviews with physics teachers. These three techniques were used in an integrated manner to identify students' initial abilities, learning needs, readiness to use technology, and the suitability of the teaching materials that had been used thus far. The initial scientific literacy assessment was designed guided by the three science literacy competencies within the PISA framework (PISA, 2025), namely the ability to explain phenomena scientifically, the ability to design and evaluate scientific investigations and critically interpret data and evidence, and the ability to research, evaluate, and use scientific information for decision-making and action. An analysis of student characteristics was conducted to determine their backgrounds, interests, motivations, learning preferences, and digital readiness. Interviews with teachers were used to gather information about the learning process, obstacles encountered, and the characteristics of available instructional materials. The results from all these stages were then used as an empirical basis for designing STEM-based electronic student worksheets tailored to the learning needs of thermodynamics in Figure 1.

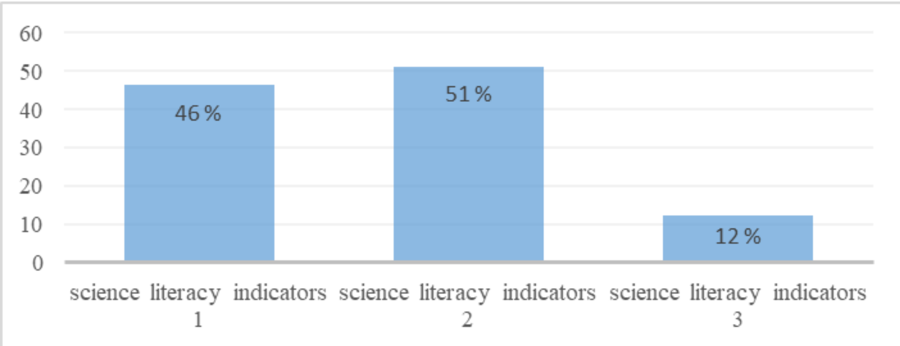

Figure 1. Results of the Students' Science Literacy Test

The initial test results in Figure 1 indicate that students' science literacy skills across all indicators remain at a low level. For the indicator "explaining phenomena scientifically," students achieved an average score of 46%, which falls into the "very low" category. These results indicate that students are not yet able to connect thermodynamics concepts to everyday phenomena in a logical, systematic, and scientific manner. Students tend to be able to recognize certain physical formulas or quantities but still struggle to explain their physical meanings and the underlying relationships between concepts. These difficulties become apparent when students are asked to explain phenomena such as temperature changes, heat transfer, or energy changes within a system. The answers provided generally emphasize mathematical procedures over conceptual reasoning. These findings suggest that the current instruction has not optimally trained students to construct scientific explanations based on relevant concepts and evidence.

The results of the pre-test administered to 30 students showed that their science literacy skills in thermodynamics remain relatively low. Students achieved an average score of 36.48 on the, with a standard deviation of 18.89. The lowest score was 5.56, while the highest reached 77.78. The distribution of student scores is presented in Table 2.

Table 2. Students' Science Literacy Test Results

Shoes %	Category	Number of Students	Percentage
81-100	Very High	0	0%
76-80	Height	1	3,33%
60-75	Enough	4	13,33%
55-59	Low	2	6,67%
≤ 54	Very low	23,	76,67%

Based on Table 2, 23 students, or 76.67%, fell into the very low category. Only one student reached the high category, and no students were in the very high category. The median score of 30.56, which is lower than the mean score, also indicates that the majority of scores are concentrated in the lower group. These findings suggest that science literacy difficulties are not limited to a few students but represent a fairly dominant pattern within the study group. Further analysis was conducted based on the three science literacy competencies measured. These competencies include the ability to explain phenomena scientifically, design and evaluate investigations and critically interpret data, and use scientific information for decision-making. These three competencies align with the core competencies in the PISA 2025 science literacy framework in Table 3.

Table 3. Student Achievement by Science Literacy Competency

Science literacy competencies	Average Score	Maximum Score	Percentage of students achieving the competency
Explaining phenomena scientifically	2.77	6	46.11
Designing and evaluating investigations and critically interpreting data and evidence	3.07	6	51.11%
Researching, evaluating, and using scientific information for decision-making and action	0.73	6	12.22

Competencies in designing and evaluating investigations and interpreting data achieved the highest score, at 51.11%. However, this score is only about half of the maximum possible score. Students generally were able to identify several basic elements of an investigation, but were not yet consistent in determining variables, evaluating the appropriateness of the design, interpreting graphs, and connecting evidence to conclusions. The ability to explain phenomena scientifically reached 46.11%. These results indicate that students are not yet fully capable of using thermodynamic concepts to explain contextual phenomena. The test instrument required students to relate the process of drying roof tiles to heat transfer and the First Law of Thermodynamics, explain isothermal processes in air conditioners, and use pressure-volume graphs to explain gas processes. The low achievement in these competencies indicates that some students still view concepts and formulas as information separate from everyday phenomena.

The most prominent difficulty lies in the ability to investigate, evaluate, and use scientific information for decision-making, with a proficiency rate of only 12.22%. This low score indicates that students struggle when they must select relevant information, assess the quality of evidence, and use it as the basis for a decision or action. This competency requires the integration of conceptual understanding, evidence-based reasoning, and the ability to present logical arguments. The score profiles of several students reveal different patterns of difficulty. Student S18 scored 5, 5, and 4 on the three competencies, with a final score of 77.78. This student demonstrated relatively balanced abilities, although they did not achieve the maximum score. In contrast, S4 scored 4 on the ability to explain phenomena and 6 on scientific inquiry, but scored 0 on the use of scientific information for decision-making. This pattern indicates that the ability to understand or design an investigation does not automatically translate into the ability to use evidence in decision-making. Group S10 scored 1, 0, and 0, with a final score of 5.56, indicating difficulties across all measured competencies.

The characteristics of the thermodynamics material also contributed to the low levels of students' science literacy. This subject matter contains relatively abstract concepts, such as systems, environments, internal energy, work, heat, and phase-change processes. Understanding this material requires students to connect real-world phenomena, visual representations, graphs, scientific concepts, and mathematical models. However, when instruction is primarily focused on computational exercises, students tend to view thermodynamics as a collection of equations that must be memorized. This situation reduces students' opportunities to understand the physical meaning of the equations and the relationships between the variables they contain. Students' difficulty in explaining phenomena and interpreting data can be understood as a result of limited learning experiences that integrate conceptual and mathematical representations. Ideal instruction in thermodynamics should include contextual phenomena, observation activities, investigations, process visualization, and data analysis. Such an approach can help students build a more comprehensive understanding and reduce the tendency toward procedural learning.

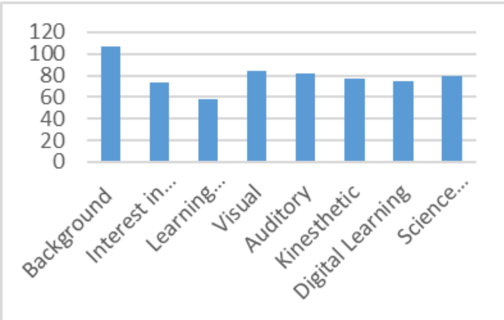

Figure 2. Analysis of Student Characteristics

The results of the analysis of student characteristics (Figure .2) indicate that most students have a relatively supportive educational background and learning environment. However, these initial conditions have not yet fully resulted in active engagement in physics learning. Some students still require teacher guidance to consistently participate in learning activities, complete assignments, and express their opinions. Students also showed interest in thermodynamics material, but this interest was not always translated into productive learning activities. Some students tended to be passive, asked few questions, and waited for direct explanations from the teacher when facing difficulties. These variations in motivation have the potential to affect students' ability to build conceptual understanding and develop science literacy. Interest that is not channeled through challenging learning activities may remain merely a fleeting curiosity without leading to deep cognitive engagement. Instructional materials need to be designed to spark curiosity through contextual problems, exploratory activities, probing questions, and tasks that allow students to take an active role in discovering concepts.

Students have diverse learning preferences, including visual, auditory, and kinesthetic learning styles. Some students find it easier to understand material through images, graphs, diagrams, animations, or videos, while others require verbal explanations and hands-on experiences. This diversity has not been fully accommodated by conventional instructional materials, which primarily consist of text and written exercises. Instructional materials dominated by symbols and equations can make it difficult for students to visualize both microscopic and macroscopic processes in thermodynamics. The use of various forms of representation is necessary so that students can see the relationships between phenomena, concepts, data, and mathematical equations. In addition, experiments or simulations can help students who need hands-on experience to understand changes in a system's variables. Instructional materials rich in representations also allow students to build understanding through learning pathways that best suit their individual characteristics. The electronic student worksheets developed should include a combination of text, illustrations, videos, graphs, simulations, and inquiry-based activities to accommodate the diversity of students' learning styles.

An analysis of digital readiness indicates that most students are already accustomed to using laptops, tablets, and smartphones. However, the use of digital devices in learning remains largely passive, such as reading materials, viewing presentations, or accessing information provided by teachers. Digital devices have not yet been optimally utilized for exploration, data processing, running simulations, or solving scientific problems. This situation indicates that having the devices does not automatically mean students are ready to use technology for meaningful learning activities. Nevertheless, students' habits in using digital devices represent a potential that supports the implementation of electronic instructional materials. electronic student worksheet can be used to guide the use of technology from consumptive activities toward investigative, reflective, and productive activities. Through electronic teaching materials, students can access visualizations, watch videos, complete assignments, record their observations, and receive feedback all within a single learning environment. The use of this technology must remain focused on learning objectives so that electronic student worksheets do not merely become digital versions of printed worksheets.

Interviews with physics teachers revealed that the instructional materials used are still dominated by worksheets and routine practice problems. These materials do not provide sufficient opportunities for students to explore, design investigations, interpret data, and draw evidence-based conclusions. The available content also fails to optimally connect thermodynamics concepts to real-world problems relevant to students' lives. As a result, learning tends to be procedural and focused on solving mathematical problems. Teachers have attempted to modify the material to better suit students' needs, but time and resource constraints have hindered their ability to develop interactive and systematic teaching materials. These findings highlight a gap between the demands of science literacy development and the characteristics of the available teaching materials. Students need learning activities that are contextual, investigative, and encourage the use of evidence, whereas the instructional materials currently in use still place greater emphasis on computational practice. This gap is one of the factors that may explain students' low ability to explain phenomena, evaluate investigations, and use scientific information.

These research findings align with those of Rawe (Rawe et al., 2025), who reported an average science literacy score of 42.8% among middle school students. That study also found low achievement in the ability to explain phenomena, design investigations, and interpret scientific data and evidence. These similarities indicate that students' difficulties are not limited to mastering factual knowledge but also arise when that knowledge must be used to construct explanations, evaluate procedures, and formulate arguments based on evidence. Mat Noor (Mat Noor, 2010), states that analyzing science literacy based on individual competencies provides deeper insights than relying on a single overall score. This approach can more specifically identify which aspects of ability have developed and which still require instructional intervention. In this study, the competency-by-competency analysis showed that the use of scientific information for decision-making is the aspect most in need of reinforcement. These difficulties are believed to be related to students' learning experiences, which have not yet provided structured practice in connecting concepts, investigations, data, and decision-making. Wang (Wang et al., 2022), found that structured inquiry activities—such as giving students opportunities to explain ideas and apply concepts to different phenomena—are positively associated with science literacy achievement. The teacher's role in providing guidance and outlining the stages of inquiry remains essential, particularly when students' initial abilities are still low.

Based on the correlation between science literacy test results, analysis of student characteristics, and interviews with teachers, there is a need for instructional materials capable of integrating conceptual understanding, the investigative process, the use of technology, solution design, and the application of mathematics. The STEM approach is considered relevant because it connects the elements of science, technology, engineering, and mathematics in solving contextual problems. In thermodynamics, the science component can be used to build an understanding of temperature, heat, work, and energy changes. The technology component can be implemented through the use of videos, simulations, or digital media to visualize abstract processes. The engineering component can be applied through activities such as designing, creating, testing, and evaluating a simple product or solution. Meanwhile, the mathematics component is used to process data, determine relationships between variables, and support the drawing of conclusions. The integration of these four components can help students see that thermodynamic concepts do not stand alone but are used in an integrated manner to explain and solve problems. The use of digital media with a STEM approach is also relevant because Asmiliyah's research (Asmiliyah et al., 2021), shows that STEM-based physics learning media can be developed appropriately and effectively, particularly to aid in presenting abstract thermodynamics material.

Activities in the electronic student worksheet need to be structured progressively in accordance with science literacy indicators that are still weak. Initial activities can begin with the presentation of contextual phenomena that encourage students to identify problems and activate prior knowledge. Next, students can be guided to formulate questions, make hypotheses, identify variables, and plan investigative steps. Data obtained through experiments, simulations, or information sources are then analyzed to discover patterns and relationships among variables. Students should also be given the opportunity to evaluate procedures, compare results, and assess the adequacy of the evidence used. In the next stage, students can be asked to evaluate information from multiple sources and use the results of their analysis to make decisions. This series of activities can transform learning from merely applying formulas into a process of constructing scientific explanations supported by evidence. The digital format allows each stage of to be presented through a combination of text, images, videos, tables, simulations, and reflective questions, making the learning experience more interactive and focused.

Overall, the results of the preliminary study indicate three key needs in thermodynamics education. First, students' science literacy remains very low, particularly their ability to use scientific information to make decisions. Second, students' interest, motivation, diversity of learning preferences, and digital readiness are not yet supported by learning activities that foster active engagement and scientific reasoning. Third, the available instructional materials are not yet sufficiently interactive, contextual, or inquiry-based. These three findings are interrelated and indicate that learning challenges stem not only from students' abilities but also from their learning experiences and the instructional materials they receive. The development of STEM-based electronic student worksheets is relevant because they can integrate real-world phenomena, inquiry-based activities, technology use, design processes, and mathematical analysis. These electronic student worksheets are expected to help students explain phenomena, evaluate investigations, interpret evidence, and use scientific information more systematically. Therefore, the results of this preliminary study provide a strong empirical basis for designing STEM-based electronic student worksheets to foster students' science literacy in thermodynamics.

4. Conclusion

Based on the results of the needs analysis, it can be concluded that physics instruction on thermodynamics still faces several challenges related to students' science literacy skills and the availability of supporting instructional materials. The results of the pre-test indicate that students' science literacy remains relatively low, particularly in their ability to explain scientific phenomena, design and evaluate investigations, and use scientific information for decision-making in accordance with the PISA 2025 science literacy indicators. An analysis of student characteristics reveals that interest in and motivation for learning Physics have not yet fully developed to their optimal potential, even though the majority of students are already prepared to use digital devices for learning. However, the use of digital instructional materials that support science literacy activities remains limited. Interviews with teachers also revealed that the instructional materials used are still dominated by textbooks, modules, and conventional worksheets that do not specifically facilitate activities such as explaining phenomena, designing investigations, and interpreting scientific data and evidence. These findings indicate a need for teaching materials that are more structured, contextual, and support students' active engagement in the learning process. Therefore, the development of STEM-based electronic student worksheet on thermodynamics is relevant as an effort to provide teaching materials that align with learning needs. The design of the developed electronic student worksheet is intended to include activities that integrate concepts from science, technology, engineering, and mathematics, while providing opportunities for students to practice applying physics concepts in the context of real-world phenomena. The effectiveness of the electronic student worksheet in improving students' science literacy still needs to be tested through further research.

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