IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 5, No. 6, November 2024
Page 1600-1615

Science Literacy Competency Profile of Science Education Students in Understanding the Concept of Thermodynamics

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DOI : https://doi.org/10.46245/ijorer.v5i6.724

Sections Info

Article history:
Submitted: November 24, 2024
Final Revised: December 3, 2024
Accepted: December 4, 2024
Published: December 7, 2024

Keywords:
Pre-service science teacher;
Science education students;
Science literacy;
Thermodynamics concepts.

ABSTRACT

Objective: This study aimed to analyze the science literacy competency profile of science education students in understanding thermodynamics concepts at the State University of Surabaya, with a specific focus on identifying competency levels and gender differences in science literacy achievement**. Method:** A quantitative descriptive research was conducted involving 35 students from Science Education Class B, selected through random sampling. Data collection was conducted using a science literacy test instrument adapted from the 2025 PISA framwork, consisting of 15 questions (10 multiple choice and 5 essay question) designed to measure three primary science compenties. **Results:** The analysis revealed that 51.42% of students achieved a proficient level, 28.58% reached an advanced level, and 20% were at a basic level. Students showed the highest competency in explaining scientific phenomena (74.4%), followed by constructing and evaluating scientific investigations (65.7%), and lowest in research and scientific information used for decision-making (60.6%). Female students exhibited slightly better performance, with a 4-point advantage over their male counterparts**. Novelty:** This study provides a detailed analysis of science literacy competencies in understanding thermodynamics among pre-service science teacher. It also incorporates the lates 2025 PISA framework and highlights gender-based performance differences. The findings provide valuable insights for developing targeted interventions in science teacher education programs, particularly in strengthening evidence-based decision-making skills and practical applications of thermodynamics concepts**.**

INTRODUCTION

Education plays a fundamental role in the development of high-quality human resources. In the era of increasingly complex globalization, the demands of competencies and skills that must be possessed by the younger generation are getting higher, especially in the field of science and technology (Sinyanyuri et al., 2022). This makes science learning one of the main focuses in the modern education system (Lubis et al., 2023). Science learning is not only limited to knowledge transfer but also includes developing critical thinking, problem-solving, and science literacy competencies (Thahir et al., 2021). Science literacy is a fundamental competency needed to understand natural phenomena, make evidence-based decisions, and contribute to societal issues related to science (Eviota & Liangco, 2020).

In the context of higher education, especially in the science education study program, science literacy is a vital competency that prospective teacher students must master. This is because they will serve a facilitator of science learning in the future and are responsible for developing the science literacy of their students in the future (Novitasari, 2018). Understanding basic scientific concepts, especially fundamental concepts such as thermodynamics, is an important foundation in the development of science literacy

(Muhajir et al., 2021). The concept of thermodynamics is an essential concept in physics learning that has many applications in daily life and various fields of technology (Permatasari et al., 2024). Although the concept of thermodynamics includes basic concept, various studies show that there are still many misconceptions and difficulties in understanding at various levels of education (Nafaida, 2018). This is a special concern, considering this concept is a prerequisite for understanding more complex advanced science concepts.

Prospective science teachers must not only grasp theoretical concepts but also relate them to everyday phenomena and communicate them effectively. This ability is an integral part of science literacy that will affect the quality of learning they do in the future (Daniah, 2020). The science literacy profile of prospective science teacher students' needs to be studied comprehensively to understand their readiness to teach science, especially the concept of thermodynamics (Sumanik et al., 2021). The results of this study can be the basis for the evaluation and development of the education program for prospective science teachers. The education study program, specially science education as a science teacher printing institution is responsible for ensuring that its graduates have adequate science literacy (Rini et al., 2021). An in-depth understanding of the concept of thermodynamics is an important indicator in assessing prospective science teachers' readiness (Nafaida, 2018). Various aspects of science literacy that need to be considered include understanding science content, science process skills, science application contexts, and attitudes toward science (Sumanik et al., 2021). In the context of thermodynamics, these aspects include conceptual understanding, the ability to make measurements and experiments, applications in technology, and awareness of the importance of these concepts in life.

Identifying students' science literacy profiles is essential in understanding their strengths and overcoming weaknesses to improve science education. Recent studies highlight the importance of aligning literacy profiles with the challenges of modern education. For example, Dinata et al. (2024) emphasized the role of science literacy in equipping students with critical thinking skills, while Sinaga et al. (2024) focused on integrating the concept of sustainability into science education. Meanwhile, Rochaenah et al. (2024) identified gaps in research related to science literacy on specific and complex topics such as thermodynamics, underscoring the need for more directed studies in this area. While previous studies have examined science literacy competencies and thermodynamics separately, this research uniquely combines both aspects through comprehensive competency profiling within the ESD framework using the ADI model, addressing a significant gap in current literature. The ADI model, which emphasizes scientific argumentation and evidence-based reasoning, has shown promise in developing and accessing scientific literacy competencies (Tucel et al., 2023), but its application in profiling thermodynamics competencies remains unexplored. The novelty of this research lies in its systematic approach to mapping science literacy competency profiles in thermodynamics learning, incorporating both ESD principles and ADI-based assessment frameworks.

This research seeks to examine the science literacy profile of pre-service science teacher students, particularly in their comprehension of thermodynamics concepts. The study centers on the question: What are the science literacy characteristics of science education students concerning thermodynamics? The uniqueness of this research lies in its emphasis on thermodynamics, a vital yet complex subject that connects physics with environmental science, framed within the context of education for sustainable

development (ESD). According to Wulandari et al. (2024) integrating sustainability into science learning not only improves literacy competencies but also prepares students for real-world problem-solving. Furthermore, Fauziah et al. (2024) further highlight the importance of evaluating literacy levels to improve teacher readiness, making this study very relevant.

The results of this study are expected to offer insight into the current state of literacy competencies among prospective science teachers, highlight strengths and identify areas that need to be improved (Sakti et al., 2021). These findings will contribute to the improvement of the curriculum and the development of more targeted educational strategies in science education (Juriyah et al., 2021) The integration of ESD in analyzing thermodynamic literacy is a new approach that addresses current gaps in research, as noted by Dinata et al. (2024), Sinaga et al. (2024), Rochaenah et al. (2024), Rochaenah et al. (2024), and Fauziah et al. (2024). The study is expected to significantly advance efforts in improving the preparation of science teachers and, ultimately, the quality of science education.

RESEARCH METHOD

The study focused on profiling the science literacy competencies of science education students in understanding the concepts of thermodynamics. The findings of this study serve as a foundational reference for considering future research goals aimed at enhancing the scientific literacy competencies of pre-service teachers, particularly in evidence-based decision-making and practical applications of thermodynamics. Figure 1 is a flowchart that is systematically designed to support the discussion of this article, which focuses on the science literacy competency profile of science education students in understanding the concept of thermodynamics. This visualization makes it easier to understand the entire research process, starting from problem identification, problem formulation, to the preparation of recommendations based on the findings obtained. The research process is summarized in the flowchart shown in Figure 1.

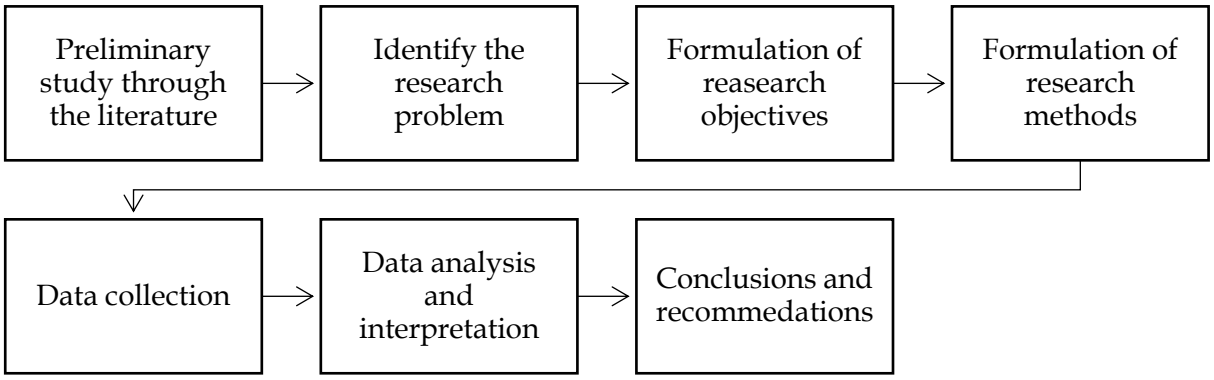

Figure 1. The research flowchart.

The research begins by examining the existing literature to explore key concepts and findings of previous research on this topic, to build a strong theoretical basis for identifying important issues and determining the focus of the research. A literature review reveals that science education students who are preparing to become teachers have not reached an optimal level of science literacy. This issue is especially relevant

given the demands of 21st-century education, which requires prospective teachers to have the ability to explain scientific phenomena, conduct research, and make evidence-based decisions. This study aims to evaluate the science literacy competency profile of science education students, especially in understanding the concept of thermodynamics. In addition, this study also seeks to identify aspects of science literacy that need to be strengthened and examine whether there are differences in competency achievement based on gender.

This study uses a quantitative approach with descriptive analysis. The research was carried out in November 2024 at the Science Education Program of the State University of Surabaya, Indonesia. A random sample was selected from a population of 144 students using a random sampling technique, namely class B Science Education, which consisted of 35 students. The science literacy test instrument is adapted from the PISA 2025 framework test with three main indicators of science competence in the concept of thermodynamics (OECD, 2023). The science literacy test instrument consists of 15 questions, which are 10 multiple-choice and 5 essays. The classification of the tests is presented in Table 1.

Table 1. Classification of scientific literacy tests.

Science Competency	Question Number	Question Form
Explaining scientific phenomena	1	Multiple Choice
	5	Multiple Choice
	7	Multiple Choice
	1	Essay
	3	Essay
Constructing and evaluating designs for scientific investigation and critically interpreting scientific data and evidence	2	Multiple Choice
	3	Multiple Choice
	6	Multiple Choice
	9	Multiple Choice
	2	Essay
Research, evaluate, and use scientific information for decision making	4	Multiple Choice
	8	Multiple Choice
	10	Multiple Choice
	4	Essay
	5	Essay

The data analysis technique of the students' science literacy level uses quantitative descriptive analysis with the calculation of the following equation (Arikunto, 2017).

$$Scientific\ literacy\ score = \frac{obtained\ score}{maximum\ score}\ x\ 100$$

After obtaining the science literacy score from the calculation using the formula above, the score will be interpreted according to the level presented in Table 2. The data obtained from this science literacy test will be analyzed based on the science competencies tested in these questions (Hidayani et al., 2021).

Table 2. Interpretation of scientific literacy score.

Score	Level	Description
75.00 < x ≤ 100.00	Advance	Able to reflect and make conceptual decisions independently very well without the need for guidance.
50.00 < x ≤ 75.00	Proficient	Able to understand texts literally and solve conceptual problems well independently.
25.00 < x ≤ 50.00	Basic	Able to search for information in science texts but still need guidance in understanding and validating concepts.
< x 25.00	Need Special Intervention	Mastery of the concept is minimal and requires intensive assistance in data collection and validation discussions with competent colleagues.

RESULTS AND DISCUSSION

Results

In this study, the science literacy competency profile of pre-service science teachers was analyzed to identify their understanding and skills in thermodynamic concepts that are fundamental in science education (Nafaida, 2018). The results show that the majority of pre-service science teachers' science literacy competencies in understanding the concepts of temperature and heat are at the proficient level. However, these results are at varying levels, with some aspects showing good mastery, while others require more attention. Based on the tests carried out, the test results are obtained as presented in Figure 2 as follows.

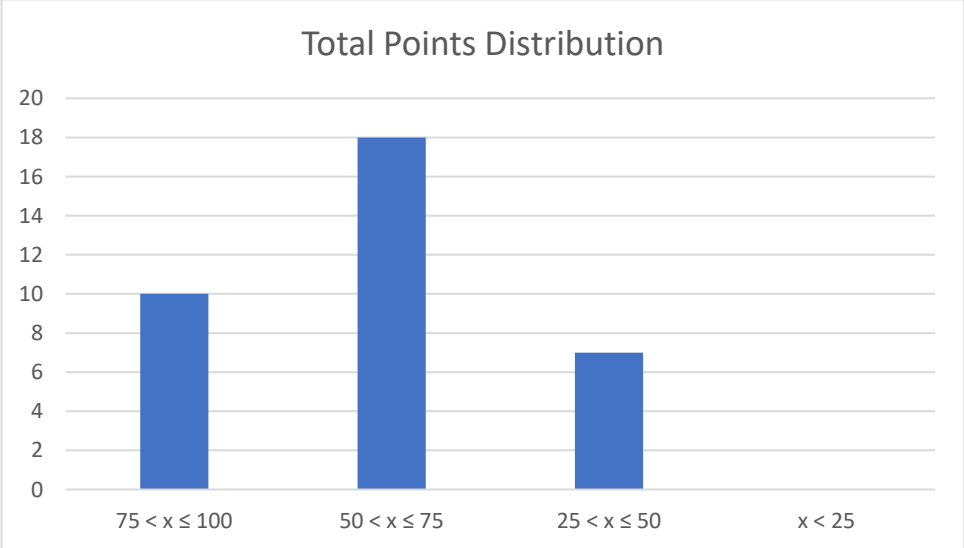

Figure 2. Total points distribution of scientific literacy test.

Figure 2 explains the science literacy test scores obtained by 35 students. The descriptive statistics of the science literacy test results are presented in Table 3.

Table 3. Descriptive statistic of scientific literacy test result.

Descriptive Statistics	Value Statistics
Number of subjects	35.00
Minimum score	95.00
Maximum score	30.00
Average score	63.74
Standard deviation	1.737

This table displays basic information related to the results of science literacy tests, including the number of participants, score range, average score, and standard deviation. This gives an overview of the distribution and variation of the scores obtained in the test. The results of the science literacy test of students can then be categorized according to their level of science literacy in Table 4 and Figure 3.

Table 4. Interpretation of scientific literacy test result.

Score	Level	Total	Percentage (%)
$75.00 < x \leq 100.00$	Advance	10	28,58
$50.00 < x \leq 75.00$	Proficient	18	51,42
$25.00 < x \leq 50.00$	Basic	7	20
$x < 25.00$	Need Special Intervention	0	0

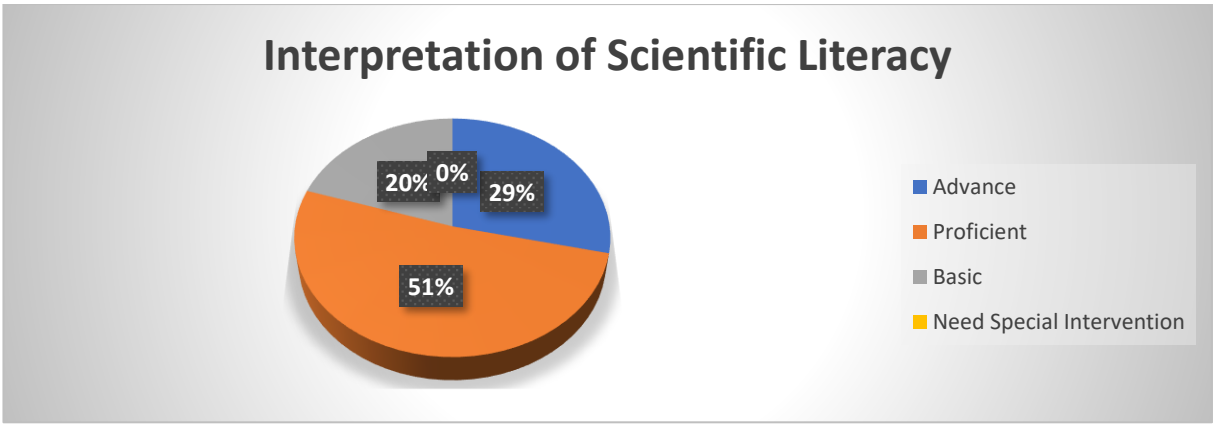

Figure 3. Interpretation of scientific literacy test result.

The results of the analysis of the science literacy profile of prospective science teacher students in understanding the concept of thermodynamics showed a fairly good distribution. The majority of students, 51.42% are at the proficient level, which means they can understand the text literally and can solve conceptual problems well

independently (OECD, 2023). As many as 28.82% of students reached the advanced level, demonstrating their ability to reflect and make conceptual decisions independently very well without the need for guidance (Deta et al., 2024). Meanwhile, 20% of students are at the basic level, Abdi et al. (2023) states that in this level, they can find information in science texts but still need guidance in understanding and validating concepts. These findings are encouraging, as no students were identified at the special intervention level, which means that no one needs intensive assistance. Overall, 80% of prospective science teacher students have demonstrated adequate ability to understand the concept of thermodynamics, although there are still 20% who need additional support to improve their understanding. The results of the science literacy test reviewed based on the science literacy competency indicators are presented in Figure 4. The students' science literacy profiles show variations in achievement in three different competencies.

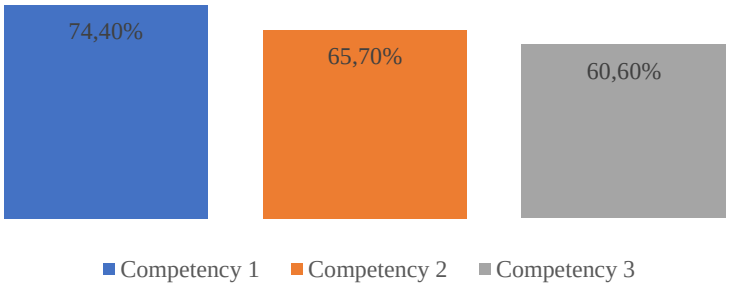

Figure 4. Percentage of scientific literacy based on science competency.

Competency 1, namely the ability to explain phenomena scientifically, reached the highest percentage of around 74.4%, indicating that students have a good understanding in explaining various phenomena with a scientific approach. Meanwhile, Competency 2, which includes the ability to design and evaluate scientific investigations and critically interpret scientific data and evidence, reached around 65.7%. Competency 3, which focuses on the ability to research, evaluate, and use scientific information for decision-making and action, showed the lowest percentage, which was around 60.6%. This data indicates that although students are quite good at explaining scientific phenomena, they still need to improve their abilities in the aspects of research, evaluation, and use of scientific information for decision-making (Fauziah et al., 2024). This pattern indicates the need for strengthening competencies related to practical application and scientific evidence-based decision-making (Antika & Marpaung, 2023).

The theme of gender equality is widely promoted, so the OECD always discusses the results of science literacy by comparing the scores of male and female students (Ministry of Education and Culture, 2023). Therefore, this study will discuss the comparison between genders as a form of science literacy profile of students. The results obtained by male and female students are shown in Figure 5.

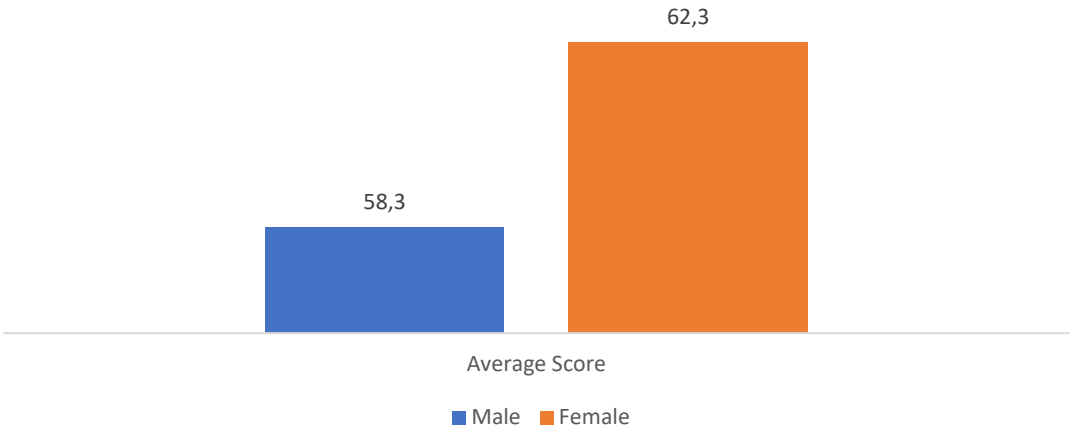

Figure 5. Average scientific literacy score comparing among gender.

The data in the graph shows a comparison of the average science literacy score between male and female students. Female students obtained a maximum average score of around 62 points, while male students obtained an average score of about 58 points, with a difference of about 4 points. This difference indicates that female students have a slightly better level of science literacy than male students in this study. Despite the differences, the gap is not very significant, indicating that both male and female students have relatively equal abilities in understanding and applying science concepts (Oberleiter et al., 2023).

Discussion

The results of the study show that the majority of prospective science teacher students (51.42%) are at the proficient level in science literacy, especially related to the understanding of thermodynamic concepts. This indicates that most students have been able to understand and analyze the basic concepts of thermodynamics independently (Kristyowati & Purwanto, 2019). This achievement is an important asset considering their role as prospective educators who will transfer their understanding of science to students in the future (Muhajir et al., 2021). The analysis of science literacy competencies showed that students had the best ability to explain phenomena scientifically (74.4%). This ability reflects a good conceptual understanding of the principles of thermodynamics and their application in everyday phenomena (Mazidah et al., 2024). However, lower achievement in the competency to evaluate and use scientific information for decision-making (60.6%) indicates the need for reinforcement in applicative aspects and evidence-based decision-making (Ilhami et al., 2024).

As many as 20% of students are at the elementary level, indicating that there is an understanding gap that requires attention. This group needs additional assistance to deepen the concept, especially in the practical application of thermodynamics. Scaffolding strategies and structured mentoring can be a solution to improve their abilities (Fakhriyah et al., 2023). The distribution of scores that tend to be normal, with the majority at the proficient level, shows the effectiveness of the learning programs that have been implemented. However, Fadilah (2024) states there is still room for improvement, especially in developing higher-order thinking skills and scientific evidence-based decision-making skills.

The ability to construct and evaluate scientific inquiry designs, which reached 65.7%, shows that students have a sufficient foundation in scientific methodology. However, it

is necessary to strengthen the aspects of data interpretation and evaluation of scientific evidence to improve their research ability as prospective educators (Ding, 2022). The findings indicate that 28.58% of students at the advanced level excelled in reflection and conceptual decision-making. This group can be a role model and help in peer learning to support the improvement of their peers' abilities (Kumar et al., 2024). The analysis revealed a positive correlation between the ability to explain scientific phenomena and the capacity to design scientific investigations. Elhai (2023) This suggests that a solid conceptual foundation aids in the development of scientific research skills.

Figure 6 presents promising findings, showing that 85.7% of students understand the concepts of temperature and heat well enough to explain related scientific phenomena. This high percentage indicates that the majority of students possess strong skills in comprehending and articulating these scientific concepts.

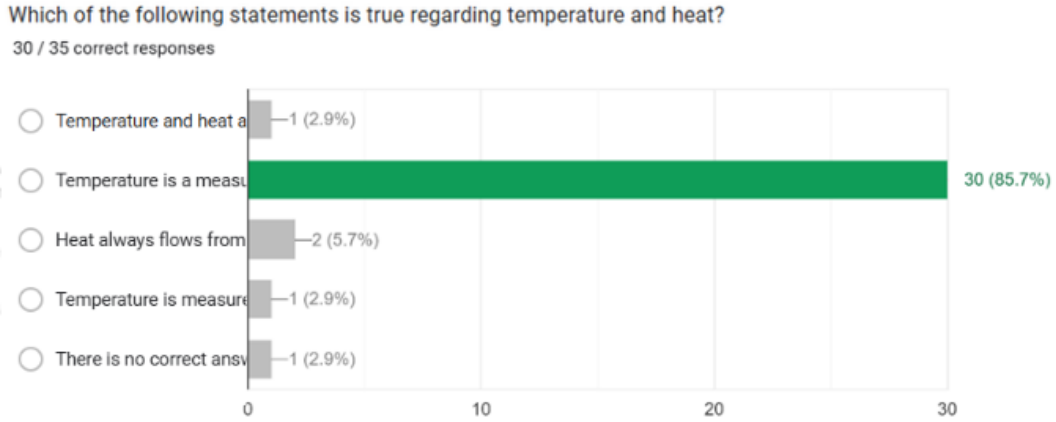

Figure 6. Results of the scientific literacy test for students in science competency 1.

This shows the success of the learning process that has been implemented (Hung & Wu, 2024). This high level of understanding has positive implications for students' readiness to master the concepts of heat and temperature. However, around 14.3% of students still have not reached optimal understanding. This implies the need for special attention to improve the understanding of the student group (Oliver & Adkins, 2020). Rini et al. (2021) states that learning strategies can be focused on strengthening concepts for students who are still experiencing difficulties while maintaining a good quality of learning for the majority of students.

The data presented in Figure 7, which shows a correct answer percentage of just 42.9%, highlights considerable challenges for students in both designing and evaluating scientific investigations as well as in critically interpreting scientific data and evidence.

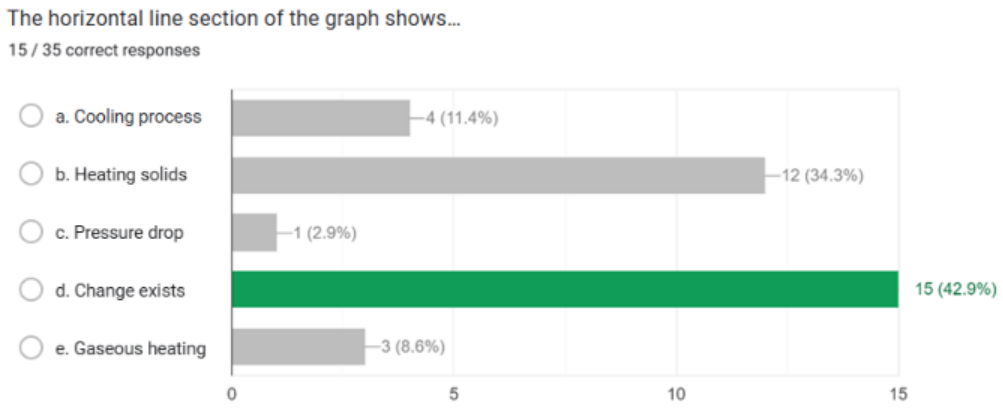

Figure 7. Results of the scientific literacy test for students in Science Competency 2.

This is a finding that needs serious attention, considering that the ability to identify the basic components of a phenomenon is a fundamental skill in science learning (Washburn et al., 2023). This low level of understanding implies the need for an in-depth evaluation of the learning methods used, especially in explaining the basic structure and components of scientific phenomena. Student ability that is still below 50% shows that there is an understanding gap that needs to be bridged through more effective and structured learning strategies (Alhusni et al., 2024).

The data in Figure 8 indicates a satisfactory level of 68.6%, but there is still a need to enhance students' science literacy skills, particularly in the area of making decisions based on scientific data.

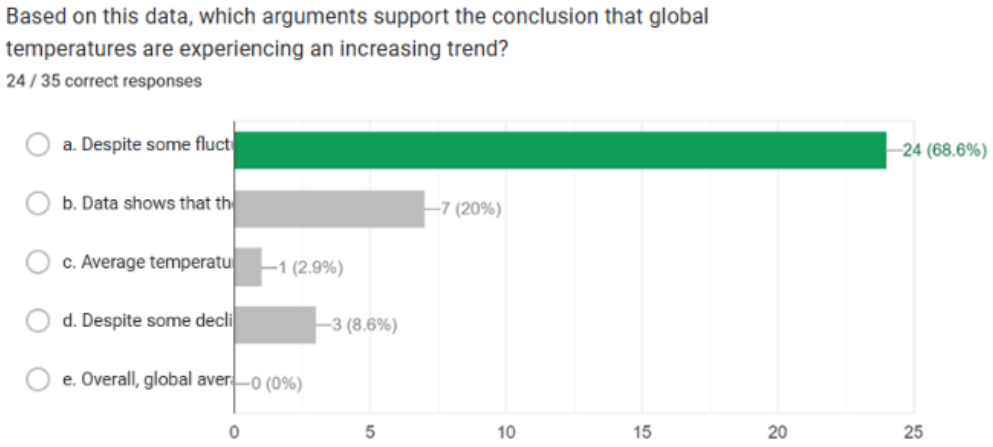

Figure 8. Results of the scientific literacy test for students in science competency 3.

This achievement indicates that most students already have a good foundation in analyzing and using scientific information, but there is still room for improvement (Alomari et al., 2023). An important implication of this data is the need to reinforce learning that emphasizes higher-order thinking skills (Berndt et al., 2021). Although more than two-thirds of students show good skills, there are still about 31.4% of students who need additional support in developing their evaluation and scientific evidence-based decision-making skills (Pörtner et al., 2024). To improve the science literacy profile of prospective science teacher students in understanding the concept of thermodynamics, the Argument-Driven Inquiry (ADI) approach can be an effective solution (Tucel Deprem

et al., 2023). ADI facilitates the development of evidence-based scientific argumentation skills, which are very relevant to the three science literacy competencies measured in this study (Purnomo et al., 2023). Novitasari et al. (2022) states that through ADI stages such as problem identification, data collection, tentative argumentation, interactive argumentation sessions, and investigative reports, students can better comprehend thermodynamic concepts while improving their science literacy comptencies.

The results show varying levels of achievement across competencies, with the lowest being in evidence-based decision-making (60.6%), which aligns with findings form Fauziah et al. (2024) who highlighted similar challenges in students' ability to critically evaluate and utilize scientific information. This highlights a specific area that requires intervention, as noted by Ilhami et al. (2024), who found that evidence-based decision-making often poses a significant challenge for students. The ADI approach offers a structured method to improve this competency by enganging students in argument-driven learning processes. The ADI approach offers a structured method to improve this competency by engaging students in argument-driven learning processes (Fakhriyah et al., 2023). Through activities such as data collection, critical evaluation of evidence, and collaborative argumentation, students develop the skills needed to make informed decisions (Novitasari et al., 2022). For instance, applying ADI in thermodynamic contexts—like evaluating the efficiency of renewable energy technologies—allows students to practice integrating scientific knowledge into meaningful, context-driven solutions (Purnomo et al., 2023). Additionally, maintaining focus on science literacy ensures that learning strategies are directly aligned with the research objectives. While real-world problem-solving is an important broader goal, this study emphasizes strengthening the specific competencies of explaining phenomena, conducting investigations, and decision-making. By contextualizing thermodynamic concepts within familiar scenarios, such as household energy use, the ADI approach ensures that students' learning experiences are both relevant and impactful.

Integrating Education for Sustainable Development (ESD) into thermodynamic learning can enhance students' science literacy by providing meaningful context (Wulandari et al., 2024). Concepts in thermodynamics, including energy transfer, entropy, and thermal efficiency, can be related to sustainability topics such as energy efficiency in green buildings, product lifecycle analysis, and renewable energy technology development (Panda et al., 2021). This method not only deepens students' understanding of these concepts but also fosters their ability to assess and apply scientific information in making decisions about sustainability issues (Ozge et al., 2023).

CONCLUSION

Fundamental Finding : This study reveals that the majority of science education students (80%) possess adequate science literacy to achieve proficiency in understanding thermodynamics concepts. The best competency was to explain scientific phenomena (74.4%), but scientific investigative and evidence-based decision-making abilities showed room for improvement. Gender differences were also found, where female students had a slightly higher level of science literacy than male students. **Implication :** These findings suggest that while the current educational program is effective in developing basic science literacy competencies, there is a need for enhanced focus on developing higher-order thinking skills, particularly in scientific investigation and evidence-based decision-making. The study recommends adopting the ADI approach and the integration of ESD contexts to enhance students' comprehensive understanding of thermodynamics

concepts. **Limitation :** This research is limited to one student population at a university and only focuses on science literacy in the thermodynamics concept. The results may not be generalizable for the broader population or other scientific concepts. In addition, the research design is descriptive, so it does not evaluate the effectiveness of a particular learning intervention. **Future Research :** Further research should explore the effectiveness of ADI approaches in various other science topics and in the broader student population. Addition, it is recommended that an experimental study with a comparison class be developed to evaluate the real impact of learning strategies on improving science literacy and higher-order thinking skills.

ACKNOWLEDGEMENTS

The researchers express their gratitude to the Ministry of Education, Culture, Research, and Technology's Puslapdik Beasiswa Unggulan program for providing the financial support and resources necessary to conduct this research.

REFERENCES

Abdi, A., Aristya, P. D., & Budiarso, A. S. (2023). Pengembangan modul flipbook digital berbasis stem materi sistem pencernaan manusia untuk meningkatkan literasi sains. *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *13*(1), 57-66. https://doi.org/10.24929/lensa.v13i1.294

Alhusni, H. Z., Habibbulloh, M., Lestari, N. A., Realita, A., Jatmiko, B., & Deta, U. A. (2024). Scientific literacy in physics learning: A bibliometric analysis from 1977 until 2023 and its impact on quality education. *E3S Web of Conferences*, *513*, 1–11. https://doi.org/10.1051/e3sconf/202451304012

Alomari, M. M., EL-Kanj, H., Topal, A., & Alshdaifat, N. I. (2023). Exploring the impact of the COVID-19 pandemic on energy literacy and conservation behavior in academic buildings of Kuwait. *Heliyon*, *9*(11), e21474. https://doi.org/10.1016/j.heliyon.2023.e21474

Antika, R. N., & Marpaung, R. R. T. (2023). Profil Literasi Sains dan Literasi Digital Mahasiswa Universitas Muhammadiyah Palembang. *Oryza (Jurnal Pendidikan Biologi)*, *12*(1), 59–68. https://doi.org/10.33627/oz.v12i1.1051

Arikunto. (2017). *Pengembangan Instrumen Penelitian dan Penilaian Program*. Pustaka Pelajar.

Berndt, M., Schmidt, F. M., Sailer, M., Fischer, F., Fischer, M. R., & Zottmann, J. M. (2021). Investigating statistical literacy and scientific reasoning & argumentation in medical-, social sciences-, and economics students. *Learning and Individual Differences*, *86*, 101963. https://doi.org/10.1016/j.lindif.2020.101963

Daniah, D. (2020). Pentingnya inkuiri ilmiah pada praktikum dalam pembelajaran IPA untuk peningkatan literasi sains mahasiswa. *Pionir: Jurnal Pendidikan*, *9*(1), 144–153. https://doi.org/10.22373/pjp.v9i1.7178

Deta, U. A., Ayun, S. K., Laila, L., Prahani, B. K., & Suprapto, N. (2024). PISA science framework 2018 vs 2025 and its impact in physics education: Literature review. *Momentum: Physics Education Journal*, *8*(1), 95–107. https://doi.org/10.21067/mpej.v8i1.9215

Dinata, R., Syafi, M., & Fakhruddin, Z. (2024). Analisis profil literasi sains siswa terhadap kajian etnosains pada pembuatan ikan salai di SMP Negeri 1 Pangkalan Kerinci. *Journal of Education*, *06*(04), 20057–20064. https://doi.org/10.31004/joe.v6i4.6042

Ding, C. (2022). Examining the context of better science literacy outcomes among U.S.

schools using visual analytics: A machine learning approach. *International Journal of Educational Research Open*, *3*(April), 100191. https://doi.org/10.1016/j.ijedro.2022.100191

Elhai, J. (2023). Special series : Scientific literacy : A more fundamental meaning. *Journal of Microbilogy & Biology Education*, *24*(1), 10–16. https://doi.org/10.1128/jmbe.00212-22

Eviota, J. S., & Liangco, M. M. (2020). Persepsi guru SMP terhadap literasi sains dan implikasinya pada pembelajaran sains di sekolah. *Jurnal Pendidikan*, *14*(September), 723–731. https://doi. org/10.37630/jpm.v14i3.1858

Fadilah, M. (2024). Analysis of students' scientific literacy abilities in biology learning: literature review. *Jurnal Bioshell: Jurnal Pendidikan Biologi, Biologi, dan Pendidikan IPA*, *13*(1), 89–98. https://doi. org/10.56013/bio.v13i1.2782

Fakhriyah, F., Rusilowati, A., Nugroho, S. E., & Saptono, S. (2023). Relationship analysis of the competence of excellent pre-service teachers: implementation scaffolding argument-driven by via inquiry learning design based on scientific literacy. *Perspektivy Nauki i Obrazovania*, *66*(6), 629–646. https://doi.org/10.32744/pse.2023.6.37

Fauziah, N., Ningsyih, S., & Khusaini, F. (2024). Profil kemampuan literasi sains mahasiswa program studi pendidkan guru sekolah dasar pada mata kuliah pendidikan lingkungan hidup: sebuah studi. *Journal of Classroom Action, 6*(1). https://doi.org/10.29303/jppipa.v6i1.6971

Hidayani, S., Jamaluddin, J., & Ramdani, A. (2021). Pemanfaatan hasil pengembangan instrumen untuk penilaian literasi sains peserta didik pada mata pelajaran IPA di SMPN 2 Mataram. *Jurnal Pengabdian Magister Pendidikan IPA*, *4*(1). https://doi.org/10.29303/jpmpi.v4i1.560

Hung, C., & Wu, H. (2024). High school science teachers ' assessment literacy for inquiry-based science instruction. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2023.2251657

Ilhami, A., Handrianto, C., & Nurbaiti, N. (2024). Profil pemahaman guru terhadap PISA: cross sectional survey. *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *14*(1), 1–8. https://doi.org/10.24929/lensa.v14i1.252

Juriyah. (2021). Profil implementasi model shared pada pembelajaran IPA terpadu di Indonesia: kajian literatur (2012-2021). *Jurnal Inovasi Penelitian dan Pengabdian Masyarakat*, *1*(1), 32–46. https://doi.org/10.53621/jippmas.v1i1.6

Kemendikbudristek. (2023). *PISA 2022 dan Pemulihan Pembelajaran di Indonesia*.

Kristyowati, R., & Purwanto, A. (2019). pembelajaran literasi sains melalui pemanfaatan lingkungan. *Scholaria: Jurnal Pendidikan dan Kebudayaan*, *9*(2), 183–191. https://doi.org/10.24246/j.js.2019.v9.i2.p183-191

Kumar, V., Choudhary, S. K., & Singh, R. (2024). Environmental socio-scientific issues as contexts in developing scientific literacy in science education: A systematic literature review. *Social Sciences and Humanities Open*, *9*(May 2023), 100765. https://doi.org/10.1016/j.ssaho.2023.100765

Lubis, M. U., Siagian, F. A., Zega, Z., Nuhdin, N., & Nasution, A. F. (2023). Pengembangan kurikulum merdeka sebagai upaya peningkatan keterampilan abad 21 dalam pendidikan. *ANTHOR: Education and Learning Journal*, *2*(5), 691–695. https://doi.org/10.31004/anthor.v1i5.222

Mazidah, L. N., Islam, U., Syarif, N., Jakarta, H., Islam, U., Syarif, N., & Jakarta, H. (2024). systematic review literature : implementasi model pembelajaran contextual

teaching and learning terhadap kemampuan literasi sains pada mata pelajaran fisika. *Seminar Nasional Sosial Sains, Pendidikan, Humaniora (SENASSDRA), 3*(1), 46–57. *http://prosiding.unipma.ac.id/index.php/SENASSDRA*

Muhajir, S. N., Lestari, P. R., & Rahayu, N. S. (2021). Tingkatan literasi sains mahasiswa calon guru fisika. *Jurnal Pendidikan UNIGA*, *15*(1), 378. https://doi.org/10.52434/jp.v15i1.1172

Nafaida, R. (2018). Pengembangan modul bahan ajar berbasis literasi sains untuk meningkatkan pemahman konsep mahasiswa pada materi termodinamika. *GRAVITASI: Jurnal Pendidikan Fisika dan Sains*, *1*, 17–19. https://core.ac.uk/download/pdf/288206114.pdf

Novitasari, N. (2018). Profil kemampuan literasi sains mahasiswa calon guru biologi. *Biosfer : Jurnal Tadris Biologi*, *9*(1), 36. https://doi.org/10.24042/biosf.v9i1.2877

Novitasari, N., Lentika, D. L., Asfiyah, M. H. Z., Maghfiroh, D. R., & Admoko, S. (2022). Pengembangan LKPD model pembelajaran argument driven inquiry untuk meningkatkan keterampilan literasi sains siswa. *ORBITA: Jurnal Pendidikan dan Ilmu Fisika*, *8*(1), 84. https://doi.org/10.31764/orbita.v8i1.8412

Oberleiter, S., Fries, J., Schock, L. S., Steininger, B., & Pietschnig, J. (2023). Predicting cross-national sex differences in large-scale assessments of students' reading literacy, mathematics, and science achievement: Evidence from PIRLS and TIMSS. *Intelligence*, *100*(April), 101784. https://doi.org/10.1016/j.intell.2023.101784

OECD. (2023). *PISA 2025 Science Framework*. *May 2023*, 1–93.

Oliver, M. C., & Adkins, M. J. (2020). "Hot-headed" students? Scientific literacy, perceptions and awareness of climate change in 15-year olds across 54 countries. *Energy Research and Social Science*, *70*(July), 101641. https://doi.org/10.1016/j.erss.2020.101641

Ozge, H., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers ' achievement , science process , and argumentation skills and their views on the ADI model. *Teaching and Teacher Education*, *121*, 103905. https://doi.org/10.1016/j.tate.2022.103905

Panda, F. M., Boy, B. Y. (2021). Implementation of phet virtual laboratory media-based physics learning on the progress of student concept mastery during the covid-19 pandemic. *Jurnal Geliga Sains (JGS): Jurnal Pendidikan Fisika, 9*(2), 123–128. http://dx.doi.org/10.31258/jgs.9.2.123-128

Permatasari, A., Dwi, A., Cahyani, R., Syihab, H. T., Rohmawati, L., & Sulistina, O. (2024). Pendekatan STEM dalam pengembangan kemampuan literasi sains. *UNESA Journal of Chemical Education*, *13*(3), 258–268. https://doi.org/10.26740/ujced.v13n3.p258-268

Pörtner, L., Riel, A., Klaassen, V., Sezgin, D., & Kievits, Y. (2024). Data literacy assessment - measuring data literacy competencies to leverage data- driven organizations. *Procedia CIRP*, *128*, 78–83. https://doi.org/10.1016/j.procir.2024.07.047

Purnomo, S., Rahayu, Y. S., & Agustini, R. (2023). Effectiveness of ADI-STEM to improve student's science literacy skill. *IJORER : International Journal of Recent Educational Research, 4*(5), 632–647. https://doi.org/10.46245/ijorer.v4i5.382

Rini, C. P., Dwi Hartantri, S., & Amaliyah, A. (2021). Analisis kemampuan literasi sains pada aspek kompetensi mahasiswa PGSD FKIP Universitas Muhammadiyah Tangerang. *Jurnal Pendidikan Dasar Nusantara*, *6*(2), 166–179. https://doi.org/10.29407/jpdn.v6i2.15320

Rochaenah, S., & Linuwih, S. (2024). Perbandingan hasil kemampuan literasi sains

peserta didik sekolah menengah atas (SMA) dan sekolah menengah kejuruan (SMK) pada materi suhu dan kalor. *Unnes Physics Education Journal*, *13*(2), 155-160. https://doi.org/10.15294/upej.v13i2.15206

Sakti, I., Nirwana, N., & Swistoro, E. (2021). Penerapan model project based learning untuk meningkatkan literasi sains mahasiswa pendidikan IPA. *Jurnal Kumparan Fisika*, *4*(1), 35–42. https://doi.org/10.33369/jkf.4.1.35-42

Sinaga, L., Prima, E. C., Nahadi, N., & Sriyati, S. (2024). Evaluasi perkuliahan zat dan energi terintegrasi ESD untuk meningkatkan literasi energi calon guru IPA. *Jurnal Pendidikan Ilmu Pengetahuan Alam (JP-IPA)*, *5*(2), 100-122. https://doi.org/10.56842/jp-ipa

Sinyanyuri, S., Utomo, E., Sumantri, M. S., & Iasha, V. (2022). Literasi sains dan asesmen kompetensi minimum (AKM): Integrasi bahasa dalam pendidikan sains. *Jurnal Basicedu*, *6*(1), 1331–1340. https://doi.org/10.31004/basicedu.v6i1.2286

Sumanik, N. B., Nurvitasari, E., & Siregar, L. F. (2021). Analisis profil kemampuan literasi sains mahasiswa calon guru pendidikan kimia. *Quantum: Jurnal Inovasi Pendidikan Sains*, *12*(1), 22. https://doi.org/10.20527/quantum.v12i1.10215.

Thahir, R., Magfirah, N., & Anisa, A. (2021). Hubungan antara high order thinking skills dan kemampuan literasi sains mahasiswa pendidikan biologi. *Biodik*, *7*(3), 105–113. https://doi.org/10.22437/bio.v7i3.14386

Tucel Deprem, S. T., Çakıroğlu, J., Öztekin, C., & Kıngır, S. (2023). Effectiveness of argument-based inquiry approach on grade 8 students' science content achievement, metacognition, and epistemological beliefs. *International Journal of Science and Mathematics Education*, *21*(4), 1057–1079. https://doi.org/10.1007/s10763-022-10299-x

Washburn, M. E., Shanks, R. A., McCartney, M., Robertson, C. L., & Segura-Totten, M. (2023). discussion of annotated research articles results in increases in scientific literacy within a cell biology course. *Journal of Microbiology & Biology Education*, *24*(1). https://doi.org/10.1128/jmbe.00154-22

Wulandari, D., Shobrina Nurul Mufida, & Saniyatul Hikmah. (2024). Preliminary developing PBL-ESDG learning tools on global warming topics: needed to train earth science literacy and student creativity. *U-Teach: Journal Education of Young Physics Teacher*, *5*(1), 15–33. https://doi.org/10.30599/uteach.v5i1.843

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