Berkala Ilmiah Pendidikan Fisika
https://ppjp.ulm.ac.id/journal/index.php/bipf
e-ISSN: 2549-2764 p-ISSN: 2337-604X
Vol 14 No 1 2026
DOI: 10.20527/bipf.v14i1.23860

Contextual Teaching and Learning-Based Physics Module: An Effective Approach to Improve Scientific Literacy

Nova Wardani, Abdul Salam*, and Sarah Miriam
Physics Education Department, Universitas Lambung Mangkurat, Banjarmasin, Indonesia
*salam@ulm.ac.id

Article Info

Article history:
Received: September 12, 2025
Accepted: December 7, 2025
Published: March 17, 2026

Keywords:
CTL
DC electricity
Physics teaching module
Scientific literacy

Abstract

The low level of scientific literacy among Indonesian students results in their limited ability to identify scientific explanations of phenomena and to accurately relate data to conclusions. In response to this issue, the present study aims to evaluate the effectiveness of a physics teaching module based on Contextual Teaching and Learning (CTL) in improving students' scientific literacy. This pre-experimental study employed a one-group pretest–posttest design. The research subjects consisted of 30 twelfth-grade students from a public senior high school in Banjarmasin. Data were collected using a scientific literacy achievement test administered before and after the implementation of the teaching module, and subsequently analyzed using the N-gain calculation. The results of the study indicate that the developed physics teaching module demonstrated medium effectiveness, with an N-gain score of 0.52. It can therefore be concluded that the physics teaching module based on the CTL approach is effective for classroom use in improving students' scientific literacy. These findings suggest that integrating the CTL approach into teaching module can serve as an alternative to support the improvement of scientific literacy among senior high school students.

To cite this article: Wardani, N., Salam, A., & Miriam, S. (2026). Contextual teaching and learning-based physics module: An effective approach to improve scientific literacy. *Berkala Ilmiah Pendidikan Fisika, 14*(1), 1-15.

INTRODUCTION

The advancement of science and information technology in the 21st century requires the education sector to prepare students to face global challenges (Kain et al., 2024; Kasse & Atmojo, 2022; Scott, 2023). One of the essential aspects within the 21st-century competency framework is the mastery of fundamental literacies, including scientific literacy (González-Pérez & Ramírez-Montoya, 2022; Konopko, 2015). Scientific literacy is understood as a competency that encompasses the ability to explain scientific phenomena, to evaluate and design scientific investigations, and to interpret data or scientific evidence (OECD, 2023). Nevertheless, the scientific literacy achievement of Indonesian students, as reflected in the 2022 PISA results, remains far below expectations. Indonesia ranked 67th out of 81 participating countries with a score of 383, which is statistically below the OECD average, and only 34% of students were able to reach the minimum proficiency level. These findings indicate the limitations of Indonesian students in identifying scientific explanations of phenomena and in accurately linking data to conclusions (Schleicher, 2023; OECD, 2023b). A similar situation is also observed at the local level. Dewantara et al., (2025) reported that the physics scientific literacy of students in Banjarmasin remains at a moderate level.

Improving students' scientific literacy requires a learning process that actively engages students in constructing their own understanding of scientific concepts, linking new ideas to their prior knowledge, and relating them to real-life contexts (Bybee, 2015; Holbrook & Rannikmae, 2009; Krajcik & Sutherland, 2010; Oberbauer et al., 2021). This view aligns with Piaget's cognitive constructivist theory, which states that learning is an active process involving students' physical, mental, and social engagement in constructing their knowledge (Jufri, 2013). In line with this, Ausubel emphasizes that learning becomes meaningful when new information can be connected to knowledge already stored within students' cognitive structures (Husamah et al., 2018). These theoretical perspectives collectively provide a strong pedagogical rationale for adopting instructional approaches that foster meaningful and contextual learning experiences. One such approach is Contextual Teaching and Learning (CTL), which emphasizes learning through its seven pillars, ensuring that the learning process is contextual, meaningful, and relevant to students' real-life situations (Johnson, 2007).

Various studies support the effectiveness of CTL in improving scientific literacy. Saniah et al. (2022) found that CTL had a substantial effect on high school students' scientific literacy in physics, with an effect size of 0.85, although the study did not elaborate on the achievement of each indicator. Priyani et al. (2019) reported that CTL had a strong influence on the context and process aspects of scientific literacy but a relatively low impact on the content aspect. Farodisa (2023) also demonstrated a significant effect of CTL on scientific literacy, although the test instrument employed was not yet fully aligned with the indicators of scientific literacy. Meanwhile, Fatmasari et al. (2013) demonstrated that CTL was effective in improving students' understanding of physics concepts, although it did not directly measure scientific literacy. However, the study by Hartini et al. (2024) reinforces these findings by showing that a SETS-based teaching module, which is also context-oriented, can improve scientific literacy, thereby emphasizing the importance of developing instructional materials that connect science with real-life contexts.

Despite these positive findings, there remains a clear research gap that warrants further investigation. Several studies have not yet elaborated on the achievement of each scientific literacy indicator in detail, nor have they aligned the assessment instruments with these indicators (Farodisa, 2023; Saniah et al., 2022). Furthermore, although the CTL approach has been proven effective in improving scientific literacy, its implementation has not been widely found in the development of teaching materials aligned with the Merdeka Curriculum, particularly in the form of a teaching module. A teaching module is a development of the lesson plan, complemented with more detailed guidance, including student worksheets and assessment instruments to assess the achievement of learning objectives (BSKAP, 2021). Therefore, it is necessary to conduct studies that specifically evaluate the effectiveness of a CTL-based physics teaching module by measuring students' performance on various indicators of scientific literacy.

Scientific literacy plays a crucial role in preparing students to participate in evidence-based decision-making and to respond to real-world issues (Bybee, 2015; Holbrook & Rannikmae, 2009). As Osborne & Allchin (2024) argue, citizens today need to be competent outsiders who can distinguish credible sources and understand scientific reasoning. Without these skills, students risk becoming passive consumers of information who struggle to connect scientific knowledge with practical decisions, and thus fail to participate effectively in science-related encounters as citizens (Bybee, 2015; Holbrook & Rannikmae, 2009; Osborne & Allchin, 2024). This situation underscores the urgency of providing learning experiences that not only convey scientific content but also actively engage students in constructing knowledge. These experiences should be delivered through a teaching module that is aligned with the Merdeka Curriculum.

Unlike previous studies that merely examined the effect of CTL on overall scientific literacy, this study systematically evaluates students' achievement across each indicator using an assessment instrument explicitly aligned with these indicators. Furthermore, the CTL approach is implemented within a physics teaching module that is coherently aligned with the Merdeka Curriculum as an integrated whole. The integration represents a novel contribution by demonstrating not only the potential of CTL to improve scientific literacy but also its practical applicability in curriculum-based classroom instruction. Accordingly, this study aims to evaluate the effectiveness of a CTL-based physics teaching module in improving students' scientific literacy.

METHODS

The study was conducted using a pre-experimental design, utilizing a one-group pretest–posttest design with a single experimental class. The subjects involved 30 twelfth-grade students from a public senior high school in Banjarmasin. The research took place from August 2024 to January 2025.

Data were collected using a scientific literacy achievement test composed of five essay items. The scientific literacy indicators used were limited to five from the competency framework by OECD (2019), and the test consisted of five essay questions corresponding to each indicator. The framework also serves as a reference in the PISA assessments of 2015, 2018, and 2022 (OECD, 2023a). The alignment between indicators and test objectives was established during the instrument development process and confirmed through expert validation, as presented in Table 1.

Table 1 Alignment between indicators and test objectives

Scientific Literacy Indicators	Test Objectives
Applying appropriate scientific knowledge	Students are able to apply the characteristics of series and parallel circuits to electrical phenomena.
Explaining the potential implications of scientific knowledge for society	Students are able to apply the concepts of electrical power and energy to everyday situations.
Evaluating ways of exploring a given question scientifically	Students are able to explain the factors that affect electrical resistance.
Transforming data from one representation to another	Students are able to apply Kirchhoff's laws to electrical circuits.
Analyzing and interpreting data and drawing appropriate conclusions	Students are able to interpret graphs to identify the characteristics of ohmic and non-ohmic resistors based on Ohm's law and/or current-voltage relationships.

To examine the impact of the CTL-based physics module, the test was administered before and after the intervention. The results were measured using Hake's (1998) normalized gain (N-gain) formula. The N-gain scores were subsequently classified with reference to Table 2. In this study, the teaching module is classified as effective when the obtained N-gain reaches at least the medium category, in accordance with the criteria proposed by Hake (1998).

Table 2 N-gain categories (Hake, 1998)

N-gain Score	Category
$\langle g \rangle \geq 0.7$	High
$0.3 \leq \langle g \rangle < 0.7$	Medium
$\langle g \rangle < 0.3$	Low

In addition, students' scientific literacy levels on each indicator were interpreted using the assessment categories in Table 3. These categories were used specifically in the analysis of the pretest–posttest results for each test item.

Table 3 Scientific literacy assessment categories
(Sudijono, 2006, as cited in Novitasari, 2018)

Interval	Category
85-100	Very good
70-84	Good
55-69	Moderate
50-54	Low
0-49	Very low

RESULTS AND DISCUSSION

The physics teaching module based on the Merdeka Curriculum implemented in this study addresses the topic of direct current (DC) electricity. From the outset, this teaching module was designed to enhance students' scientific literacy through the implementation of the CTL approach. In general, the module consists of three main components: general information, core activities, and appendices (BSKAP, 2022).

The module was implemented across four instructional meetings, with each meeting corresponding to one official classroom meeting in the school's schedule. Each meeting lasted within the range of 2×45 to 3×40 minutes, depending on the time allocation structure of the school's daily timetable. One subtopic was taught in each meeting. The first meeting covers the characteristics of ohmic and non-ohmic resistance, integrated with the concept of electrical resistance, as both are closely related in explaining the properties of a conductor's resistance. The second meeting examines the characteristics of series-parallel circuits integrated with Kirchhoff's First Law, considering that parallel circuits are closely related to the current-branching rules stipulated in the law. The third meeting focuses on Kirchhoff's Second Law as a reinforcement for analyzing voltage and current in closed circuits. The fourth meeting addresses electrical power and energy as applications of the previous concepts to understand the utilization of electricity in everyday life. The learning activities in this module combine several instructional models. Direct instruction (DI) was applied in the first meeting (Arends, 2010), guided inquiry in the second and third meeting (Sutman et al., 2008), and cooperative learning in the fourth meeting (Arends, 2010). The selection of these models is tailored to the characteristics of the material in each meeting to ensure the achievement of learning objectives while supporting the development of students' scientific literacy.

The effectiveness of the developed physics teaching module was evaluated based on the N-gain scores calculated from students' pretest and posttest results on items designed to assess their scientific literacy (Hake, 1998). The test instruments were developed based on scientific literacy indicators relevant to contextual problems in the topic of DC electricity. The obtained data were used to evaluate the extent to which the teaching module could enhance students' scientific literacy. Table 4 summarizes the pretest and posttest results, along with the calculated N-gain and its category.

Table 4 Results of the N-gain calculation

Pretest Score			Posttest Score			Average N-gain	Category
Min.	Max.	Average	Min.	Max.	Average		
0	24.2	2.99	11	98.2	53.85	0.52	Medium

The pretest was conducted to assess students' scientific literacy before they received treatment using the CTL-based physics teaching module (Sugiyono, 2021). The pretest results indicated that the lowest score was 0, while the highest score reached only 24.2 out of a maximum of 100. Subsequently, the posttest was administered after four sessions of learning using the teaching module (Sugiyono, 2021). The posttest results showed that the lowest score increased to 11, while the highest score reached 98.2 out of a maximum of 100. This improvement indicates the development of scientific literacy in some students after participating in learning using the CTL-based teaching module. The N-gain results presented in Table 4 fall into the medium category, indicating that the developed physics teaching module can be considered effective in improving both achievement test and students' scientific literacy.

In addition, students' scientific literacy was also analyzed based on their responses to each item of the achievement test administered during the pretest and posttest. Each test item was developed based on scientific literacy indicators, so that the assessment results provide an overview of the average scores achieved for each indicator. Each indicator corresponds to specific DC electricity subtopics. The categorization of these scores follows the criteria presented in Table 3. The detailed average scores of the students, along with the proportion of achievement for each indicator, are presented in Table 5. As shown in Table 5, the students' scientific literacy improved on three indicators, reaching good and/or moderate category, while the remaining two indicators only showed improvement to the very low category. This overview provides a general picture of the areas in which the CTL-based module was most and least effective.

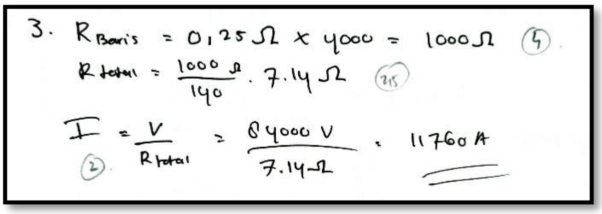
Table 5 Achievement of scientific literacy indicators

Item Number	Scientific Literacy Indicator	Pretest		Posttest	
		Average Score	Proportion	Average Score	Proportion
3	Applying appropriate scientific knowledge	2.49 (VL)	0.02	67.01 (M)	0.67
5	Explaining the potential implications of scientific knowledge for society	4.52 (VL)	0.05	43.11 (VL)	0.43
2	Evaluating ways of exploring a given question scientifically	1.78 (VL)	0.02	77.33 (G)	0.77
4	Transforming data from one representation to another	2.84 (VL)	0.03	23.33 (VL)	0.23
1	Analyzing and interpreting data and drawing appropriate conclusions	3.73 (VL)	0.04	64.20 (M)	0.64

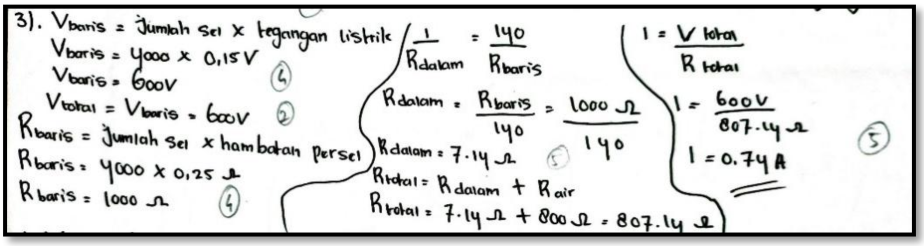
Note: G = good; M = moderate; VL = very low

The pretest averages shown in Table 5 appear very low because most students had limited prior knowledge of DC electricity concepts. Both pretest and posttest scores were calculated using the same 0–100 scale. Therefore, the substantial differences between them reflect genuine improvement rather than inconsistencies in data presentation. The varying degrees of improvement across indicators also align with the differences in difficulty and cognitive demand of the corresponding items.

The first indicator, the ability to apply appropriate scientific knowledge, was measured using item number 3, which involved a global context regarding the electric eel phenomenon. This item requires students to apply knowledge of the characteristics of series and parallel circuits to calculate the electric current that can be generated by the electric eel as a biotic organism living in aquatic environments. Based on Table 5, the average score on this item showed an improvement after the intervention. The proportion of correct responses, which was initially only 0.02, increased to 0.67, with the level of scientific literacy categorized as moderate. Figure 1, respectively, present the students' responses before and after the intervention, highlighting their ability to apply knowledge about the characteristics of series and parallel circuits.



(a)



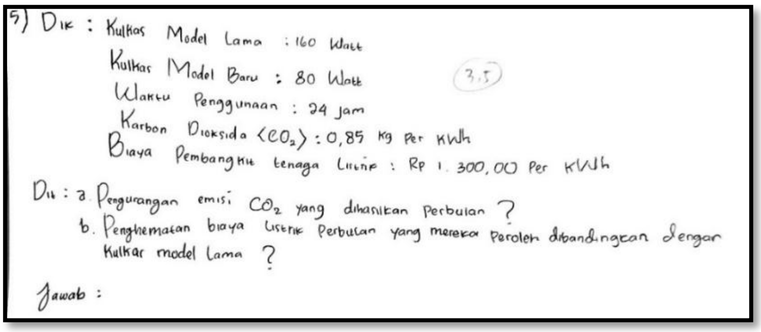
(b)

Figure 1 (a) Figure 1 Student's answer on applying scientific knowledge (pretest) and (b) Student's answer on applying scientific knowledge (posttest)

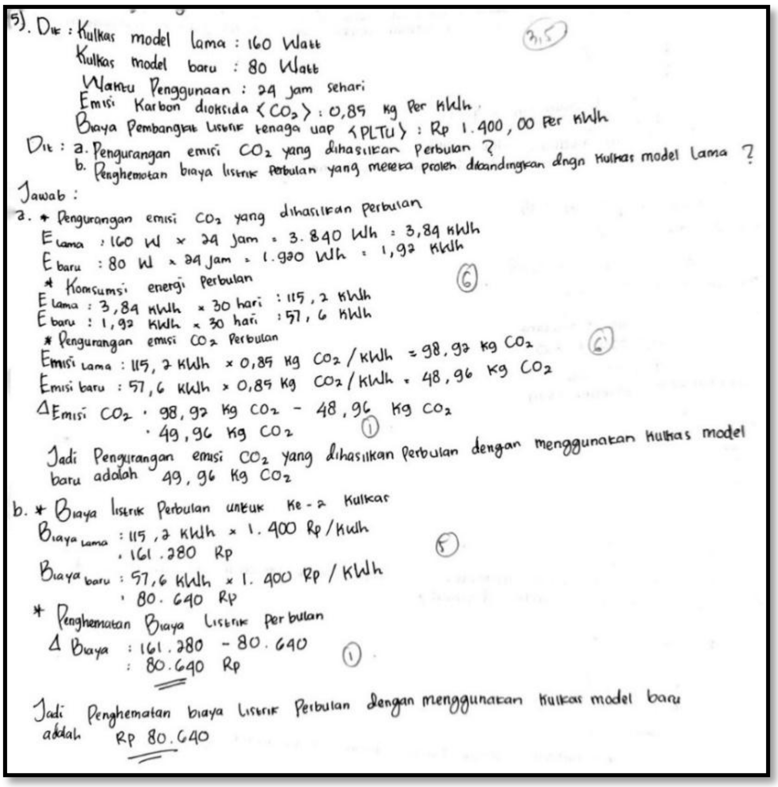
The improvement in achievement for the first indicator indicates that applying scientific knowledge in varied contexts has a positive impact on students' understanding. This is reinforced by the results on an equivalent item in Student Worksheet 2c, which addressed a different phenomenon, namely the lamp circuit in a building. Although the contexts of the items in the student worksheet and the achievement test differed, students were still able to apply their knowledge to a new phenomenon. These findings are in line with Wiggins & McTighe (2005) who argue that applying knowledge in new and contextual situations is a crucial component of deep learning. These results are also consistent with Azmarita et al. (2019), who found that contextualized student worksheets can enhance scientific literacy by connecting the material to daily life in accordance with students' responses. Thus, the contextual approach provides students with the opportunity to connect learned knowledge to real-world situations, thereby reinforcing their understanding.

The second indicator, the ability to explain the potential implications of scientific knowledge for society, was measured using item number 5, which addressed the phenomenon of energy-efficient refrigerators and their implications for carbon emissions and electricity costs. During the learning phase, students were also presented with socio-scientific issues through Student Worksheets 4a and 4b, such as selecting the location for high-voltage transmission towers and calculating the power and energy of electrical generators. However, the achievement for this indicator only increased from 0.05 to 0.43, with the level of scientific literacy still categorized as very low. Figure 2 respectively show the students' responses before and after the intervention, illustrating their ability to explain the societal implications of power and energy issues.

This low achievement indicates that students are not yet fully able to integrate scientific understanding with its implications for society. This is in line with Sadler (2004), who stated that understanding scientific concepts alone is insufficient for addressing questions related to socio-scientific issues, as students also need to consider moral and ethical aspects. Another factor that may have influenced the results is the placement of the item as the last question, which could have affected students' concentration and cognitive effort. In line with Schuman & Presser (1996), the order of items in an assessment instrument can influence responses due to fatigue effects, making questions positioned at the end more likely to be answered suboptimally



(a)



(b)

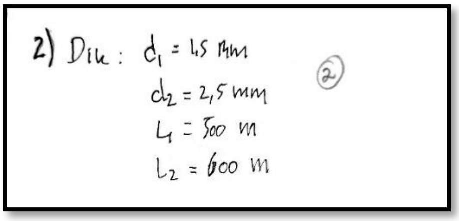
Figure 2 (a) Figure 2. Student’s answer on explaining potential implications for society (pretest) and (b) Student’s answer on explaining potential implications for society (posttest)

.

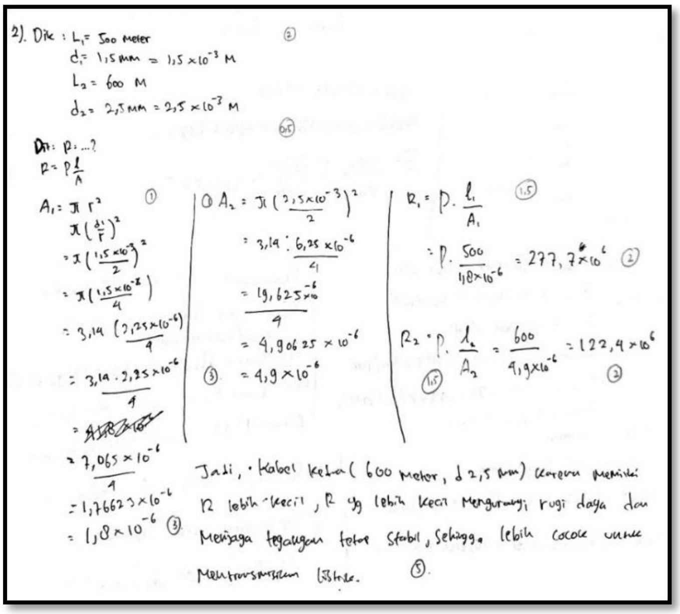
Similar findings were reported by Mijaya et al. (2019), who indicated that this indicator tended to be low due to students’ limited initial readiness for learning, as well as their difficulties in tackling items based on lengthy texts and real-world contexts. This is also consistent with field data, where some students reported not adequately preparing themselves and not reviewing the material prior to the test, resulting in outcomes that do not fully reflect their actual abilities. Wolf et al. (1995, as cited in Zerpa et al., 2011) also emphasized that students’ lack of motivation and effort due to test conditions can threaten the validity of result interpretations, as test outcomes may not accurately represent their true abilities. As a result, items that are not inherently difficult may appear more challenging because students do not exert their best effort.

Thus, this suggests that the low scores obtained may not fully reflect students' intellectual capacities, but can also be influenced by their low learning motivation. To address this issue, the ARCS motivational model (Attention, Relevance, Confidence, Satisfaction) was developed by Keller (1987) can be considered in the development of future teaching modules. The ARCS model emphasizes four key aspects: capturing attention to maintain students' focus; establishing relevance by linking the material to real-life contexts; fostering confidence in completing tasks; and creating a satisfying learning experience that promotes sustained motivation. Integrating this strategy into CTL-based teaching modules will strengthen efforts to address the low learning motivation identified in the study.

Next, the analysis focused on the third indicator, evaluating ways of exploring a given question scientifically. This indicator was measured using item number 2, set in a personal context, selecting the most appropriate electrical cable based on variations in length and diameter. This item requires students to evaluate a simple investigation design by considering the physical factors that influence electrical resistance. The results indicated a significant increase in achievement for this indicator, with the proportion of correct responses rising from 0.02 to 0.77 after instruction using the CTL approach. This achievement places students' scientific literacy at a good level, simultaneously indicating that the developed teaching module is effective in fostering students' evaluative skills in scientific investigations. Figure 3 shows the student's responses before and after the intervention, illustrating how the student evaluated solutions to problems related to electrical resistance.



(a)



(b)

Figure 3 (a) Figure 3. Student's answer on evaluating scientific ways of exploring the question (pretest) and (b) Student's answer on evaluating scientific ways of exploring the question (posttest)

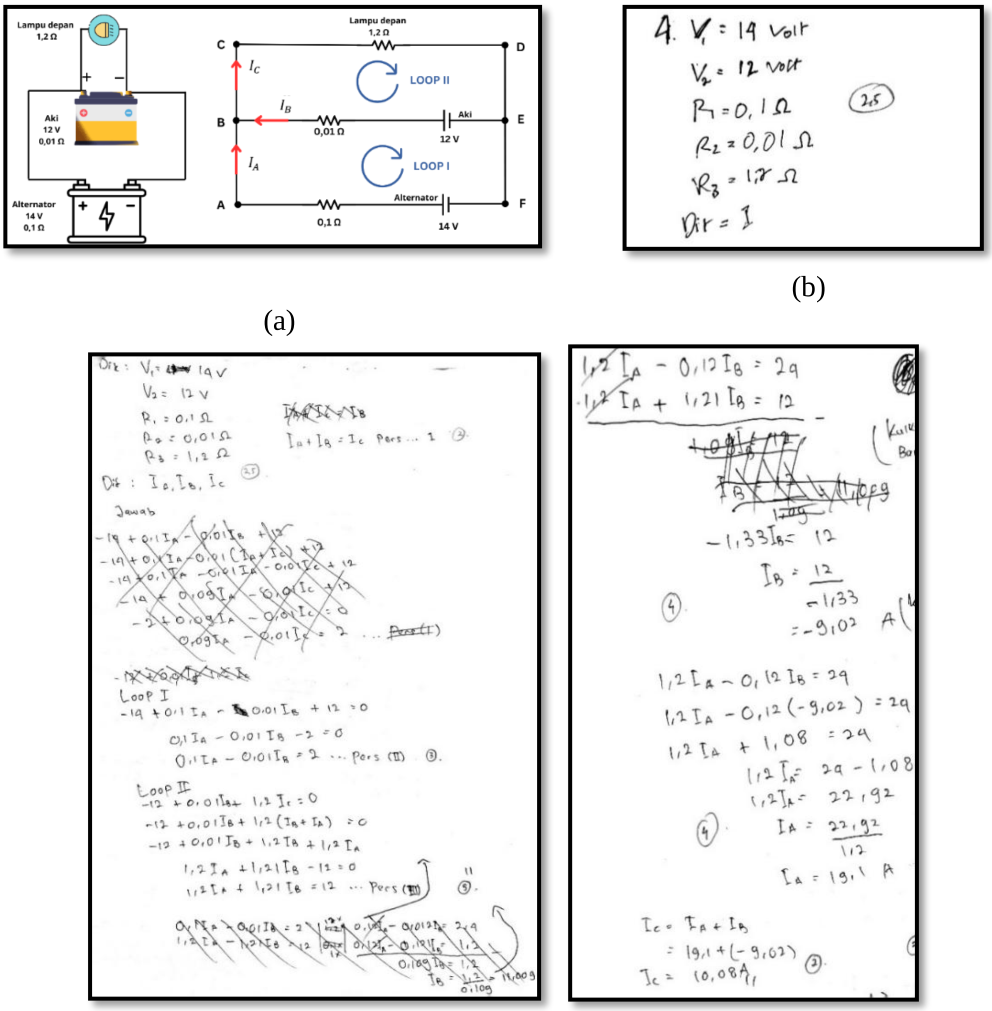
Interestingly, this indicator exhibited the most substantial improvement among all, despite its demand for higher-order thinking skills. This outcome can be explained by the use of a personal context that is highly relevant to students' daily experiences. Because the context feels personal, students can picture themselves in the situation, making them more mentally involved. This finding is in line with Bennett et al. (2006) who state that when students are interested and motivated by learning experiences they perceive as meaningful, their engagement increases, and this has a positive impact on their understanding. Hence, questions framed in a personal context are more meaningful to students because they connect with their everyday lives, which helps them understand scientific concepts better.

The fourth indicator, concerning the ability to transform data from one representation to another, was evaluated using item number 4, which examined the application of Kirchhoff's law in the motorcycle headlamp circuit powered by a battery. This question required students to interpret information provided in the form of a circuit diagram and subsequently transform it into a mathematical representation in order to solve the problem. The findings indicate that this indicator showed only a slight improvement, with the proportion of correct responses rising from 0.03 to 0.23, while students' scientific literacy skills remained within the very low category. Figures 8 and 9, respectively, present the students' responses before and after the intervention, illustrating their ability to transform circuit diagram information into mathematical representations using Kirchhoff's law, following the circuit diagram shown in Figure 4.

Among all indicators, the fourth showed the least notable improvement. Firstly, transforming data from visual to mathematical representation demands both a deeper conceptual understanding and advanced abstract reasoning skills. Students are required not only to understand the meaning of the symbols in the circuit diagram, but also to connect them with Kirchhoff's laws and carry out the appropriate calculation procedures. Second, the low performance may be attributed to students' limited practice in converting between visual, verbal, and mathematical representations, making them more prone to confusion when facing tasks that demand multi-representational understanding.

This low achievement indicates that students encountered difficulties in transforming information from visual representations in the form of circuit diagrams into mathematical representations of Kirchhoff's law. This may be attributed to a weak foundational understanding of Kirchhoff's law and the limited time available for repeated practice with similar problem types. Ainsworth (2006) explains that when students are not sufficiently familiar with the representations used, they often pay attention only to the surface features of a diagram or equation and struggle to grasp the underlying conceptual relationships. The lack of conceptual understanding makes it difficult for students to transfer knowledge accurately across different forms of representation. Therefore, strengthening conceptual understanding and providing repeated practice are essential to improving performance on this indicator.

Although previous studies such as Ainsworth (2006) and Lin et al. (2013) highlight the importance of scaffolding and multi-representational design in supporting students' transformation skills, these approaches were not explicitly integrated into the current study. This is because the intervention was limited to the use of a CTL-based teaching module developed in accordance with the national curriculum and tailored to the learning time available. Consequently, the DeFT-based strategies could not be systematically incorporated into the instructional design. Nonetheless, the findings of Ainsworth and Lin remain relevant, and future research may consider integrating structured multi-representational scaffolding to further improve students' skills in transforming data across representations.

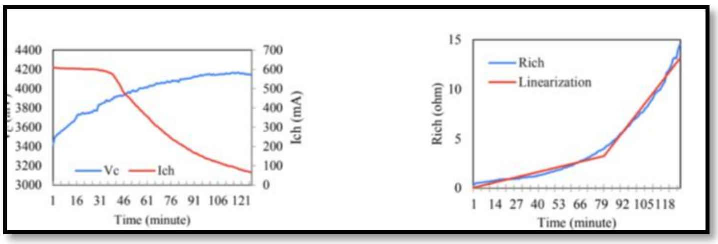


(a) (b) (c)

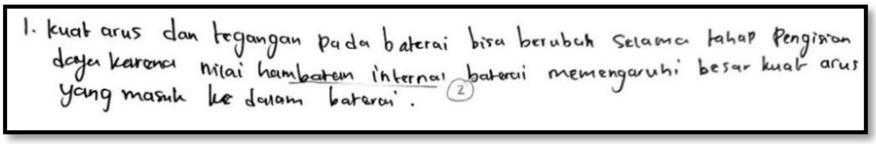
Figure 4 (a) Circuit diagram used in item number 4, (b) Student's answer on transforming data representations (pretest), (c) Student's answer on transforming data representations (posttest)

The last indicator, which refers to the ability to analyze and interpret data and to draw appropriate conclusions, was assessed through item number 1. This item presented the context of battery charging and required students to interpret both current–voltage and resistance-time graphs in order to explain the characteristics of non-ohmic resistance. According to the study results, the average score on item number 1 increased after the implementation of CTL-based learning, with the proportion of correct answers rising from 0.04 to 0.64, placing students' scientific literacy for this indicator in the moderate category.

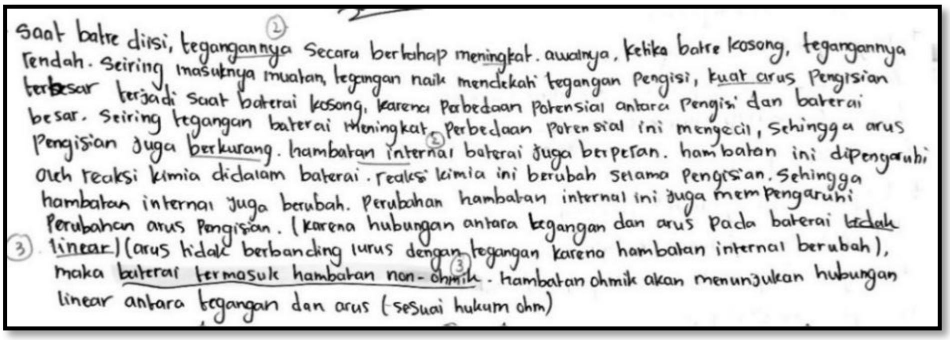
This item presents a visual representation in the form of a graph illustrating the problem of mobile phone battery charging. This is in line with ChanLin (2001) who stated that students still developing their physics competence benefit more from the use of static graphs than from text, as this can reduce cognitive load. With the aid of the graph, students find it easier to interpret the changes in current and voltage, thereby enabling them to draw the required conclusions. Figure 5 presents the current–voltage and resistance–time graphs used in Item 5. Figure 5, respectively, shows the student's responses before and after the intervention, highlighting their ability to analyze and interpret both the current-voltage and resistance-time graphs in order to draw conclusions about the characteristics of the battery as a resistor.



(a)



(b)



(c)

Figure 5 (a) Graphs used in item number 1 (Adapted from Kurniawan et al., 2020), (b) Student’s answer on analyzing and interpreting data (pretest), and (c) Student’s answer on analyzing and interpreting data (posttest)

Based on the classroom implementation, the N-gain score obtained from students’ pretest and posttest results was classified as medium. The implementation of the CTL-based teaching module also demonstrated an improvement in students’ scientific literacy, although two indicators remained in the very low category. According to the effectiveness criteria established in this study, a teaching module is categorized as effective when the N-gain reaches at least the medium category. Nevertheless, the findings suggest that the developed teaching module is effective in improving students’ scientific literacy.

CONCLUSION

Students’ responses for each scientific literacy indicator increased following exposure to the CTL-based physics teaching module. The indicator with the highest proportion of student responses was evaluating ways of exploring a given question scientifically, which fell into the good category. The next highest indicators were applying appropriate scientific knowledge, followed by analyzing and interpreting data and drawing appropriate conclusions, both categorized as moderate. However, the indicators of explaining the potential implications of scientific knowledge for society and transforming data from one representation to another were still categorized as very low. Overall, the effectiveness of the CTL-based physics teaching module, as reflected by the N-gain score of 0.52, was classified as medium. These findings suggest that implementing the CTL approach through physics teaching modules can serve as an alternative to support the enhancement of scientific literacy at the senior high school level.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS STATEMENT

This article was collaboratively written by three authors with complementary roles from the planning stage to the publication process. The first author contributed to data collection and drafted the initial manuscript. The second author focused on designing the research instruments, ensuring methodological feasibility, and editing the structure and language of the article. The third author was responsible for developing the instruments, assisting in field research activities, and performing the final editing to align the manuscript with publication standards. All authors have read, reviewed, and approved the final version of the manuscript prior to publication.

AI DISCLOSURE STATEMENT

The author used ChatGPT and DeepL during the manuscript preparation process solely for translation and language refinement. After using these tools, the author carefully reviewed and revised the entire manuscript and assumes full responsibility for the content and accuracy of the work. All aspects of the research design, data collection, data analysis, and conclusion drawing were conducted entirely by the author without the assistance of artificial intelligence (AI).

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Department of Physics Education, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, and the school where this research was conducted for their support and provision of facilities.

REFERENCES

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, *16*(3), 183–198. https://doi.org/10.1016/j.learninstruc,2006.03.001

Arends, R. I. (2010). *Learning to Teach* (9th ed.). McGraw-Hill Education.

Azmarita, T., Helmi, & Azis, A. (2019). Pengembangan lembar kerja peserta didik (LKPD) luar kelas berbasis kontekstual untuk meningkatkan literasi sains XI MIPA SMAN 8 Maros. *Jurnal Sains Dan Pendidikan Fisika*, *15*(1), 69–74. https://doi.org/10.35580/jspf.v15i1.9410

Bennett, J., Lubben, F., & Hogarth, S. (2006). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Wiley Interscience: Science Education*, *91*(3), 347–370. https://doi.org/10.1002/sce

BSKAP. (2021). *Kajian akademik kurikulum untuk pemulihan pembelajaran*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia.

BSKAP. (2022). *Panduan pembelajaran dan asesmen pendidikan anak usia dini, pendidikan dasar, dan menengah*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia.

Bybee, R. (2015). Scientific Literacy. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp. 944–947). Springer. https://doi.org/10.1007/978-94-007-2150-0_178

ChanLin, L.-J. (2001). Formats and prior knowledge on learning in a computer-based lesson. *Journal of Computer Assisted Learning*, *17*(4), 409–419. https://doi.org/10.1046/j.0266-4909.2001.00197.x

Dewantara, D., Fajariah, I., Zainuddin, & Hartini, S. (2025). Physics science literacy profile using local wisdom-based instrument and profile of Pancasila students in particle dynamic. *Momentum: Physics Education Journal*, *9*(1), 58–68.

Farodisa, A. (2023). Pengaruh model contextual teaching and learning terhadap kemampuan literasi sains siswa kelas V SDN Kraton 3. *Sinar Dunia: Jurnal Riset Sosial Humaniora Dan Ilmu Pendidikan*, *2*(3), 230–240. https://doi.org/10.58192/sidu.v2i3.1174

Fatmasari, D., Zainuddin, & An'nur, S. (2013). Aplikasi pendekatan contextual teaching and learning (CTL) untuk meningkatkan pemahaman konsep siswa. *Berkala Ilmiah Pendidikan Fisika*, *1*(1), 70–81. https://doi.org/10.20527/bipf.v1i1.863

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of education 4.0 in 21st century skills framework: Systematic review. *Sustainability*, *14*(1493), 1–31. https://doi.org/10.3390/su14031493

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Hartini, S., Khairiyah, N., Wati, M., Dewantara, D., Zainuddin, Ismail, Saehena, S., & Rahman, N. F. A. (2024). Student's science literacy skill through implementation of integrating teaching modules with SETS approach on renewable energy topics. *Journal of Engineering Science and Technology*, *19*(5), 1693–1715.

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education*, *4*(3), 275–288.

Husamah, Pantiwati, Y., Restian, A., & Sumarsono, P. (2018). *Belajar dan pembelajaran*. UMM Press.

Johnson, E. B. (2007). *Contextual teaching and learning: menjadikan kegiatan belajar-mengajar mengasyikkan dan bermakna*. MLC.

Jufri, A. W. (2013). *Belajar dan pembelajaran sains*. Pustaka Reka Cipta.

Kain, C., Koschmieder, C., Matischek-Jauk, M., & Bergner, S. (2024). Mapping the landscape: A scoping review of 21st century skills literature in secondary edition. *Teaching and Teacher Education*, *151*(104739), 1–27.

Kasse, F., & Atmojo, I. R. W. (2022). Analisis kecakapan abad 21 melalui literasi sains pada siswa sekolah dasar. *Education and Development*, *10*(1), 124–128. https://doi.org/10.37081/ed.v10i1.3322

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*, *10*(3), 2–10. https://doi.org/10.1007/BF02905780

Konopko, J. (2015). *Unlocking the potential of the smart grid*. World Economic Forum.

Krajcik, J. S., & Sutherland, L. M. (2010). Supporting students in developing literacy in science. *Science*, *328*(5977), 456–459. https://doi.org/10.1126/science.1182593

Kurniawan, T. A., Natajaya, A., Priambodo, P. S., & Wibisono, G. (2020). Real time monitoring state-of-charge battery using internal resistance measurements for remote applications Real time monitoring state-of-charge battery using internal resistance measurements for remote applications. *Journal of Physics: Conference Series*, *1528 01203*. https://doi.org/10.1088/1742-6596/1528/1/012034

Lin, S.-Y., Maries, A., & Sigh, C. (2013). Student difficulties in translating between mathematical and graphical representations in introductory physics. *AIP Conf. Proc.*, *1513*, 250–253. https://doi.org/10.1063/1.4789699

Mijaya, N. P. A. P., Sudiatmika, A. A. I. A. R., & Selamet, K. (2019). Profil literasi sains siswa SMP melalui model pembelajaran levels of inquiry. *JPPSI: Jurnal Pendidikan Dan Pembelajaran Sains Indonesia*, *2*(2), 161–171. https://doi.org/10.23887/jppsi.v2i2.19385

Novitasari, N. (2018). Profil kemampuan literasi sains mahasiswa calon guru biologi. *Biosfer: Jurnal Tadris Biologi*, *9*(1), 36–44. https://doi.org/10.24042/biosf.v9i1.2877

Oberbauer, A. M., Lai, E., Kinsey, N. A., & Famula, T. R. (2021). Enhancing student scientific literacy through participation in citizen science focused on companion animal behaviour. *Translational Animal Science*, *5*(3), 1–10. https://doi.org/10.1093/tas/txab131

OECD. (2019). PISA 2018 assessment and analytical framework. In *PISA 2018 Assesment and Analytical Framework*. OECD Publishing.

OECD. (2023a). *PISA 2022 assessment and analytical framework*. OECD Publishing.

OECD. (2023b). *PISA 2022 results factsheets Indonesia*. OECD Publishing.

Osborne, J., & Allchin, D. (2024). Science literacy in twenty-first century: informed trust and the competent outsider. *International Journal of Science Education*, 1–22. https://doi.org/10.1080/09500693.2024.2331980

Priyani, Y., Nofiana, M., & Julianto, T. (2019). Pengaruh model contextual teaching and learning (CTL) terhadap literasi sains siswa pada materi keanekaragaman hayati di MAN 2 Banyumas. *Jurnal Kiprah*, *7*(1), 1–12. https://doi.org/10.31629/kiprah.v7i1.996

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*, *41*(5), 513–536. https://doi.org/10.1002/tea.20009

Saniah, A., Sukarno, & Rahim, A. (2022). Pengaruh model pembelajaran contextual teaching and learning terhadap kemampuan literasi sans siswa di SMA. *Physics and Science Education Journal (PSEJ)*, *2*(2), 110–115. https://doi.org/10.30631/psej.v2i2.1514

Schleicher, A. (2023). *PISA 2022 insights and interpretations*. OECD Publishing.

Schuman, H., & Presser, S. (1996). *Questions and answers in attitude surveys: Experiments on question form, wording, and context*. Sage Publications, Inc.

Scott, C. L. (2023). The futures of learning 3: What kind of pedagogies for the 21st century? *International Journal of Business Education*, *164*(1), Article 1. https://doi.org/10.30707/IJBE164.1.1690386168.68154

Sugiyono. (2021). *Metode penelitian pendidikan*. Alfabeta.

Sutman, F. X., Schmuckler, J. S., & Woodfield, J. D. (2008). *The science quest using inquiry/discovery to enhance student learning, grades 7-12* (1st ed). Josey Bass.

Wiggins, G., & McTighe, J. (2005). *Understanding by Design*. Association for Supervision and Curriculum Development.

Zerpa, C., Hachey, K., van Barneveld, C., & Simon, M. (2011). Modeling student motivation and students' ability estimates from a large-scale assessment of mathematics. *SAGE Open*, *1*(2), 1–9. https://doi.org/10.1177/2158244011421803

AUTHOR PROFILES

NOVA WARDANI
Email: 2110121120002@mhs.ulm.ac.id
Affiliation: Physics Education Department, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin, Indonesia.

ABDUL SALAM
Email: salam@ulm.ac.id
expertise in physics learning,
Affiliation: Physics Education Department, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin, Indonesia.
Google Scholar, Sinta, Scopus, Orchid ID

SARAH MIRIAM
Email: sarah_pfis@ulm.ac.id
expertise in physics learning,
Affiliation: Physics Education Department, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin, Indonesia.
Google Scholar, Sinta, Scopus