Jurnal Penelitian Pembelajaran Fisika
Vol. 17 Issue 2 – April 2026, p157-163
p-ISSN 2086-2407, e-ISSN 2549-886X
Available Online at http://journal2.upgris.ac.id/index.php/JP2F
DOI: 10.26877/jp2f.v17i2.3395

Analysis of Students' Scientific Literacy Dimensions in Citizen Science Projects

Harto Nuroso[1,2], Ernawati Saptaningrum[1], Ummi Kaltsum[1], Wawan Kurniawan[1] and Joko Siswanto[1]
[1]Program Studi Pendidikan Fisika Universitas PGRI Semarang, Jl. Sidodadi Timur no. 24 Semarang, Indonesia

[2]E-mail: hartonuroso@upgris.ac.id

Received: 23 January 2026. Accepted: 10 March 2026. Published:30 April 2026.

Abstract. The low scientific literacy of Indonesian students, consistently below the international average, according to the PISA survey, demands contextual and participatory learning innovations. This study aims to analyze the dimensions of scientific literacy in high school students through the implementation of a citizen science project on the topic of mechanical energy, evaluating its effectiveness as a pedagogical strategy to address the persistently low science literacy of Indonesian students. The research uses a mixed-methods approach, focusing on analyzing the use of mechanical energy in students' daily transportation. The results show a significant improvement in students' understanding of physics concepts, particularly in the context dimension (the ability to apply knowledge to real situations) and the attitude dimension (interest in science). However, the study also identifies an area requiring further development: the science process dimension, specifically the skills to critically evaluate data and scientific processes. In conclusion, citizen science successfully transformed learning from theoretical memorization into a meaningful, authentic inquiry experience. For sustainability and optimization, a systemic commitment is needed to integrate this approach into the curriculum, along with adequate training and resource support for teachers, to equip students with the science competencies required for the 21st century.

Keywords: science literacy, citizen science, high school students, physics learning

1. Introduction

Amidst the 21st-century landscape marked by technological disruption and the complexity of global issues, mastery of scientific literacy has shifted to become a fundamental core competency for citizenship. The OECD, through the Programme for International Student Assessment (PISA), defines scientific literacy as the capacity to use scientific knowledge, identify questions, and draw evidence-based conclusions to understand and inform decisions about nature and its changes [1]. This concept has been further reinforced in subsequent PISA cycles, positioning scientific literacy as a key competency for effective participation in a knowledge-based society and economy [2]. This ability is no longer merely an academic requirement, but rather a necessity for every individual to engage critically and constructively in public discourse [3]. This transformation places scientific literacy on a par with basic skills such as reading and writing, which are essential for navigating the modern world [4,5]. Thus, strong scientific literacy, whose development aligns with advances in physics and technology, is the foundation for a resilient society ready to face challenges such as climate change and biotechnological breakthroughs.

Unfortunately, the reality in Indonesia is still far from these expectations. Indonesian students' achievements in scientific literacy according to the PISA survey are consistently below the international average. The low level of scientific literacy in Indonesia, marked by 53.60% of students in the very low category, demands the provision of evaluation instruments that can comprehensively represent scientific thinking skills [6]. The low level of scientific literacy among Indonesian students primarily indicates underdeveloped scientific reasoning and the use of evidence in authentic contexts, rooted in teaching that emphasizes memorization rather than inquiry, argumentation, and contextual problem-solving [7,8]. This condition demands pedagogical innovation capable of transforming science learning from a teacher-centered and theoretical approach to an applicable and meaningful learning experience. This low ranking is a serious alarm, indicating a fundamental gap between the curriculum taught and the competencies measured in global assessments. Therefore, systematic efforts are needed to build students' capacity to connect scientific knowledge to real-world problems they face daily. Without a paradigm shift in learning, Indonesia risks continuing to lag behind in equipping its young generation with the intellectual tools necessary for the 21st century.

One strategic alternative proposed in the current science education literature is the integration of citizen science projects [9]. Citizen science encourages students to play an active role as contributors to real-world scientific research, such as environmental or biodiversity monitoring. This approach offers authentic inquiry-based and participatory learning, where students are directly involved in the scientific cycle, from data collection and analysis to communication of results within the context of relevant local issues [10,11]. Through this involvement, it is hoped that not only cognitive aspects will be strengthened, but also attitudes and science process skills.

Despite its significant potential, empirical studies on the implementation of citizen science in formal education in Indonesia, particularly at the senior high school level, remain very limited. Previous research on physics learning in Indonesia has focused largely on the development of higher-order thinking skills and the use of innovative models/technologies, rather than on citizen science or community engagement [8,12,13]. Meanwhile, studies that comprehensively and integratedly investigate how citizen science shapes all dimensions of students' scientific literacy, as defined in the PISA framework, remain a significant gap in the literature.

Based on this gap, this study was designed to analyze the dimensions of high school students' scientific literacy in implementing a citizen science project. The analytical framework refers to the four dimensions of scientific literacy according to the OECD: (1) Content Dimension (knowledge of scientific facts, concepts, and theories), (2) Process Dimension (ability to design investigations, interpret data, and evaluate evidence), (3) Context Dimension (ability to apply science in personal, social, and global situations), and (4) Attitude Dimension (interest, curiosity, and attitudes toward science and related issues) [1].

It is hoped that the findings of this study can provide an empirical contribution to the development of innovative science learning models in Indonesia. By mapping the development of each dimension of scientific literacy through a citizen science approach, the results of this study can serve as a reference for educators and policymakers in designing more holistic and contextual learning experiences to sustainably boost students' scientific literacy achievements.

2. Method

This research uses a mixed methods explanatory sequential model [14]. This design is implemented by collecting and analyzing quantitative data first. This quantitative phase is then followed sequentially by qualitative data collection. The purpose of the qualitative phase is to deepen, explain, and enrich the findings obtained from the initial quantitative analysis. Thus, this sequence allows researchers to build a more comprehensive and contextual understanding.

The subjects in this study involved 32 eleventh-grade high school students. Participants were selected purposively, with the primary criterion being the school's willingness to implement the inquiry-based learning approach as part of the intervention. The citizen science project focused on Physics, specifically the concepts of Work and Energy. The chosen real-world context was the analysis of mechanical energy in high school students' daily transportation activities, so the learning material was directly linked to their life experiences.

During the project, students took an active role as citizen scientists. Their task was to identify energy consumption in everyday transportation activities. Next, they calculated the amount of energy involved. The culminating activity was analyzing the efficiency or energy use of various modes of transportation they commonly use, such as walking, cycling, riding a motorcycle, or riding in a private car. Through this series of activities, the science learning process was experienced in an applied and meaningful way.

This study used three main instruments to collect data. The first instrument was the Science Literacy Test developed based on the PISA framework, which serves to quantitatively measure three dimensions of science literacy (content, process, and context) [1]. The Content dimension includes indicators: identifying facts/concepts of work and energy; the Process dimension: designing simple investigations, interpreting data; the Context dimension: applying concepts to personal/social situations. The second instrument was the Participatory Observation Sheet, which was used to document in detail the scientific attitudes and process skills of students during the project implementation. The third instrument was a Semi-structured Interview Guide, which was aimed at a selected sample of participants to explore their personal experiences, attitudes, and contextual understanding related to the project.

Data analysis was conducted in an integrated manner in accordance with the sequential design used. Quantitative data obtained from the tests were analyzed using descriptive statistics. This analysis aimed to map the initial and final profiles of students' scientific literacy abilities numerically. Meanwhile, qualitative data derived from observations and interviews were analyzed using thematic analysis techniques [15,16]. This thematic analysis process aimed to identify developmental patterns in the attitudinal dimension and provide elaboration and contextual explanations for the quantitative findings. The integration of these two analysis results was designed to produce a holistic understanding of the impact of the learning intervention.

3. Results and Discussion

The results of the study revealed a varied profile of students' scientific literacy across four dimensions following their involvement in a citizen science project on mechanical energy analysis in high school students' daily transportation. In the content dimension, conceptual understanding of physics related to work, energy, and power showed significant improvement, particularly in the ability to calculate work ($W = F \times d$), kinetic energy, and potential energy. However, some students still had difficulty distinguishing the concept of work in mechanics from everyday concepts. In the process dimension, the skills of designing simple observations and processing quantitative data from measuring distance (d): measured using the Google Maps application or a fitness tracker on a cellphone developed very well, although skills in evaluating data validity and sources of error still need improvement. In the context dimension, students' ability to apply concepts to analyze real-life situations, such as calculating the energy expended to overcome friction, showed the most prominent improvement, indicating the acquisition of scientific literacy for citizenship. Meanwhile, in the attitude dimension, observations and interviews documented an increase in interest, intrinsic motivation, and a sense of responsibility regarding energy consumption issues, which was manifested through student initiatives in energy conservation campaigns at school. Overall, the project demonstrated a positive impact on developing functional scientific literacy by connecting abstract physics concepts to authentic, everyday contexts.

The quantitative achievement profiles of the science literacy test, both initial and final, can be seen in Table 1.

Table 1. Distribution of students' science literacy scores (n=32) in the pretest and posttest.

Dimension	Average Pretest	Average Posttest	Improvement
Content (max 30)	14.2	22.5	8.3
Process (max 35)	16.8	27.1	10.3
Context (max 35)	15.5	29.3	13.8
Total (max 100)	46.5	78.9	32.4

Qualitative data from the interviews enriched and explained the quantitative findings. For example, one student stated, "*At first, I was confused about connecting the work and energy formulas to fuel consumption. After we actually recorded and calculated the distance and fuel consumption of my motorbike for a week, I understood that the concept was real and could directly impact daily expenses*" (Student A, Interview). This quote illustrates the integration of content understanding (energy unit conversion) with the context of personal application. Observations also noted the emergence of a sense of responsibility, as reflected in another student's statement, "*Now I prefer to ride a bicycle for short distances. I feel like I'm partly responsible for the energy waste and pollution I've been producing*" (Student B, Interview).

The discussion of the results of this study interprets the findings that the context and attitude dimensions show the most dominant development, while the process dimension in the evidence evaluation stage remains relatively weak. This indicates that the main strength of citizen science projects lies in their ability to provide meaningful context and build scientific identity in students [10,11]. The highest increase in the context dimension aligns with the essence of citizen science as a bridge between classroom science and social applications, where students see the direct relevance of physics in their lives [17]. Meanwhile, weaknesses in the evaluation aspect of the process dimension confirm the OECD findings that higher-order thinking skills (such as critically assessing the validity of data) generally remain a challenge in many education systems.

These findings align with and enrich previous research. Significant improvements in the attitude and context dimensions support research suggesting that authentic project-based learning increases engagement and perceived relevance of science [18–20]. However, the finding that evaluation skills in the scientific process remain weak provides a new nuance. Studies in Indonesia indicate that inquiry learning is still predominantly procedural, especially in structured inquiries, resulting in suboptimal in-depth reasoning based on data; comprehensive guided inquiries are closer to the essence of scientific reasoning [21–23]. Thus, the citizen science project in this study successfully strengthened the application and attitude aspects, but still needs to be designed more explicitly to train critical evaluation skills.

The advantage of this approach, as observed, is its ability to spark student engagement through active roles as contributing scientists and authentic contextualization of learning. Students not only learn formulas but also use them to generate concrete recommendations that impact their surroundings. This creates situated learning that encourages internalization of concepts [18,24].

However, implementing this approach in schools faces several real challenges. Key challenges include more flexible time management outside of routine schedules, the availability of basic measurement facilities, and the need for teacher skills in guiding open-ended investigations and managing student data [25–27]. Without systemic support, it is difficult to maximize the potential of citizen science sustainably.

Theoretically, this study provides important implications by strengthening the conceptual framework that scientific literacy is a multidimensional construct that can be developed integratively through participatory learning environments [28,29]. This study enriches the discussion on scientific literacy for citizenship with empirical evidence from the Indonesian context. Practically, these findings provide implications for physics learning in the form of a concrete model (a mechanical energy analysis project on students' daily transportation) that teachers can adopt to teach the topic of Work and Energy. The practical recommendation is the need for specific scaffolding integrated into the project design to intentionally train critical data evaluation and analysis skills, so that the four dimensions of scientific literacy can develop in a more balanced manner.

4. Conclusion

Based on the overall analysis, this study concludes that the implementation of a citizen science project on the topic of mechanical energy analysis in students' daily transportation can significantly develop the multidimensional scientific literacy profile of high school students. The main findings indicate that the dimensions of context (real-life applications) and attitudes (interest and responsibility) experienced the most dominant development. The dimension of process (data processing skills) also increased, although critical evaluation skills still need strengthening, while the dimension of content (conceptual understanding) showed a solid improvement.

The significance of this research lies in demonstrating that a participatory learning approach and authentic contexts are effective strategies for addressing the challenge of low scientific literacy in Indonesia. The citizen science project successfully transformed physics learning from merely mastering formulas into meaningful experiences that foster scientific citizenship, where students see themselves as agents capable of contributing to solving real-world problems in their communities.

Based on the findings and discussion, several recommendations are proposed. For teachers, it is recommended to design and integrate simple citizen science projects with contextual physics topics, accompanied by explicit scaffolding to practice critical data analysis and evaluation skills. For schools and policymakers, it is recommended to provide support in the form of teacher training, flexible time allocation, and basic measurement facilities to create a sustainable inquisitive learning ecosystem. For future research, it is recommended to explore the effectiveness of the citizen science model in other physics topics, develop more in-depth attitude assessment instruments, and examine factors that influence the sustainability of this approach in the regular curriculum.

Acknowledgements

The researcher would like to thank the Research Institute for Research and Community Service (LPPM) of Universitas PGRI Semarang for permitting and providing funding for this research, as well as the physics teachers and students of SMAN 1 Semarang who agreed to participate in this research.

Daftar Pustaka

[1] OECD 2019 *PISA 2018 Results (Volume I): What Students Know and Can Do* vol I

[2] Putri P N, Rachmadiarti F, Purnomo T and Satriawan M 2025 Measuring Scientific Literacy of Students' Through Environmental Issues Based on PISA 2025 Science Framework *J. Penelit. Pendidik. IPA*

[3] Kelp N, McCartney M, Sarvary M, Shaffer J and Wolyniak M 2023 Developing Science Literacy in Students and Society: Theory, Research, and Practice *J. Microbiol. Biol. Educ.* **24**

[4] Khairiyah U, Suryanti, Widodo W and Mariati P 2025 Improving science literacy and

communication skills: a study using development of the read, explore, application (REA) learning model based on ethnoscience *Multidiscip. Sci. J.*
[5] Wulan N S, Iskandar S, Nurbayan Y, Fajrussalam H, Hikmatunisa N P, Yogiarni T, Ravy H and Nurdiansyah N 2025 Study correlation between science literacy and reading literacy: A study on prospective elementary teachers as an implementation of SDGs *Multidiscip. Rev.*
[6] Valio F A, Safira L, Aulliyah U A and Suwarna I 2025 Development of a Science Literacy Test for Junior High School Students Based on the PISA 2025 Framework *J. Pendidik. MIPA* **16** 1377–405
[7] Widiana L V W, Prayitno B and Sugiharto B 2024 Framework problem solving based augmented reality media to empower scientific explanation skill *JPBI (Jurnal Pendidik. Biol. Indones.*
[8] Yana A, Koes-H S, Fawaiz S and Rizal F 2025 Students' Scientific Reasoning in Physics through Procedural and Conceptual E-Scaffolding in Modelling Instruction: A Quasi-Experimental Study *J. Learn. Dev.*
[9] Bonney R, Phillips T B, Ballard H L and Enck J W 2016 Can citizen science enhance public understanding of science? *Public Underst. Sci.* **25** 2–16
[10] Wargers A, Queral J, Mölenberg F, Tarro L, Elphick C, Kalogerakou E, Karagiannis A, Llauradó E, Manios Y, Mavrogianni C, Murray C, Vlachopoulos D, Williams C, Jansen W and Solà R 2023 Citizen Science to improve healthy and active living among adolescents in four European countries: a protocol of the cluster randomised controlled trial of the Science Engagement to Empower aDolescentS (SEEDS) project *BMJ Open* **13**
[11] Pocock M, Hamlin I, Christelow J, Passmore H-A and Richardson M 2023 The benefits of citizen science and nature-noticing activities for well-being, nature connectedness and pro-nature conservation behaviours *People Nat.*
[12] Ramadhan M, Mundilarto M, Ariswan A, Irwanto I, Bahtiar B and Gummah S 2023 The Effect of Interface Instrumentation Experiments-Supported Blended Learning on Students' Critical Thinking Skills and Academic Achievement *Int. J. Interact. Mob. Technol.* **17** 101–25
[13] Ena S I, Zaturrahmi Z and Dini K 2025 Students' creative thinking in physics: An investigation of the effectiveness of the CPS instructional model *Int. J. Innov. Res. Sci. Stud.*
[14] Creswell J W and Creswell J D 2018 *Research design: Qualitative, quantitative, and mixed methods approaches* (SAGE Publications)
[15] Hagaman A, Rhodes E, Aloe C, Hennein R, Peng M, Deyling M, Georgescu M, Nyhan K, Schwartz A, Zhou K, Katague M, Egger E and Spiegelman D 2025 How Are Qualitative Methods Used in Implementation Science Research? Results From a Systematic Scoping Review *Implement. Res. Pract.* **6**
[16] Braun V and Clarke V 2006 Using thematic analysis in psychology *Qual. Res. Psychol.* **3** 77–101
[17] Nurdiansyah F, Khumaedi M and Kriswanto K 2025 Pembelajaran Berbantuan E-Modul untuk Meningkatkan Capaian Pembelajaran Kognitif Fungsi Bagian-bagian Mesin Frais *Panthera J. Ilm. Pendidik. Sains dan Terap.* **5** 642–653
[18] Rehman N, Zhang W, Mahmood A, Fareed M Z and Batool S 2023 Fostering twenty-first century skills among primary school students through math project-based learning *Humanit. Soc. Sci. Commun.* **10** 1–12
[19] Wang X and Sitthiworachart J 2024 Effects of Project-based Learning on Students' Learning Performance and Engagement in Computer Science *Eff. Proj. Learn. Students' Learn. Perform. Engagem. Comput. Sci.* **30** 3391–3402
[20] Wang C, Song L and Jiang J 2025 The impact of project-based learning on university physics education: enhancing cognitive skills and core competencies *Front. Psychol.* **16**
[21] Mariyanti N, Sulistri E and Anitra R 2023 Pengaruh Model Inkuiri Terbimbing Berbasis Lingkungan Terhadap Keterampilan Proses Sains Siswa Kelas V dalam Pembelajaran IPA di SDN 12 Singkawang *CENDEKIA J. Ilmu Sos. Bhs. dan Pendidik.* **3** 198–208
[22] Nathasyah A, Idris M and Suryani I 2023 Efektifitas Model Pembelajaran Inkuiri untuk Mengukur Kemampuan Berpikir Logis Siswa Kelas IV pada Pembelajaran IPS di SD Negeri 08 Pedamaran *Indones. Res. J. Educ.* **3** 994–1001
[23] Karim H, Lodang H and Nurhadi M 2021 Perbandingan Minat dan Hasil Belajar Siswa yang

Dibelajarkan dengan Model Pembelajaran Inkuiri Terbimbing dengan Inkuiri Terstruktur pada Mata Pelajaran Biologi *Biol. Teach. Learn.* **4**

[24] Srikoon S, Khamput C and Punsrigate K 2024 Effects Of Stemen Teaching Models On Mathematical Literacy And Mathematical Problem-Solving *Malaysian J. Learn. Instr.* **21** 79–115

[25] Alarcon D A U, Talavera-Mendoza F, Paucar F H R, Caceres K S C and Viza R M 2023 Science and inquiry-based teaching and learning: a systematic review **8**

[26] Strat T T S, Henriksen E and Jegstad K 2023 Inquiry-based science education in science teacher education: a systematic review *Stud. Sci. Educ.* **60** 191–249

[27] Dah N M, Noor M S A M, Kamarudin M Z and Azziz S S S A 2024 The impacts of open inquiry on students' learning in science: A systematic literature review *Educ. Res. Rev.* **43**

[28] Vistarini L 2025 Optimalisasi Penggunaan Teknologi Digital sebagai Strategi Efektif dalam Meningkatkan Literasi Sains di Sekolah Dasar *J. New Trends Sci.* **3** 11–21

[29] Tanjung M R, Asrizal A and Usmeldi U 2022 Pengaruh Pembelajaran IPA Berbasis STEM Terhadap Literasi Sains dan Hasil Belajar Peserta Didik: Suatu Meta Analisis *J. Penelit. Pembelajaran Fis.* **8**