Lontar Physics Today (e-ISSN: 2828-0970)
Vol. 4 No. 3 November 2025, p 136-141
Available online at http://journal.upgris.ac.id/index.php/upt
DOI: 10.26877/lpt.v4i3.25078

# Citizen Science in Science-Physics Class: Building Contextual Climate Change Literacy

**Elvina Risma Andini and Joko Siswanto***

*Physics Education Study Program, PGRI Semarang University, Jl. Lontar No. 1 Semarang, Indonesia*

* Corresponding author(s), e-mail: jokosiswanto@upgris.ac.id

**Article Info:**

**Article History:**
Received: 3 October 2025
Accepted: 16 October 2025

**Keywords:**
Citizen science, science-physics learning, climate change literacy

**Abstract:**

This study aims to examine the potential of integrating Citizen Science (CS) into science-physics learning as a pedagogical approach that can help shape a contextual understanding of climate change. This study used the Systematic Literature Review (SLR) method with reference to the PRISMA 2020 guidelines. The review process was carried out through several steps, namely problem identification, literature search in various databases, determination of inclusion and exclusion criteria, selection of articles, and thematic analysis of literature that met the criteria. Of the 35 articles identified, 15 were selected for further in-depth analysis. The literature review indicates that the integration of CS into science-physics learning can effectively improve cognitive aspects (scientific literacy, critical thinking skills, and creativity), affective (positive attitudes towards the environment, self-confidence, and relationships with the scientific community), and behavioral (awareness of pro-environmental actions). However, significant behavioral changes are still limited, and implementation faces obstacles such as limited time, lack of teacher competence, and integration with the official curriculum. The uniqueness of this study lies in mapping the contribution of Citizen Science in strengthening students' climate literacy comprehensively. Citizen Science serves not only as a science learning method but also as a medium of scientific and social participation that connects scientific knowledge, environmental awareness, and concrete action.

## 1. Introduction

Climate change is considered one of the main challenges to human survival. Rising global temperatures, rising sea levels, reduced biodiversity, and the increasing frequency of meteorological disasters are clear evidence of ongoing climate problems [1]. The 2005 Millennium Ecosystem Assessment (LMEA) report and various IPCC documents confirm that environmental damage and climate change present increasingly dangerous risks, especially for the younger generation who will feel the impacts later in life [2]. Therefore, education plays a crucial role in building critical awareness, environmental knowledge, and adaptation skills so that students can contribute as agents of change in facing climate challenges.

Unfortunately, the practice of science and physics education in schools still faces various obstacles. The learning style commonly used in Indonesia tends to focus on memorization, prioritizes teacher instruction, and emphasizes low cognitive abilities. This situation impacts students' lack of critical thinking, creativity, and scientific literacy [3]. The results of the 2022 PISA survey show that the level of scientific literacy of Indonesian students remains low (68 out of 81 countries), indicating the need for updates in teaching methods that are more relevant, involve participation, and focus on 21st-century skills [3].

Many studies indicate the great potential of Citizen Science (CS) in education, finding that student involvement in the iNaturalist project can increase interest in science, increase confidence in taking environmental action, and deepen understanding of the scientific process [4]. At the elementary education level, it was shown that the application of CS to environmental pollution issues can significantly improve the creative thinking skills of elementary school students, with the N-Gain of the experimental group reaching 59.56, while the control group was only 21.17 [5]. In addition, research conducted on high school students revealed that the CS project-based learning model has a positive impact on critical and creative thinking skills when compared to conventional learning methods [3].

Not only in the cognitive field, CS also plays a role in increasing sustainability literacy. CS project-based learning with a focus on biodiversity in environmentally friendly schools was able to make 93% of students achieve results that exceed the minimum completion standards, in the good to excellent category [6]. This finding is in line with the results of international research that shows that CS can connect students with real environmental phenomena, strengthen relationships with nature, and encourage the formation of attitudes that support the environment [2][7].

The relevance of Citizen Science (CS) to climate change issues is gaining increasing attention. Young people's participation in climate-related CS projects has the potential to directly contribute to IPCC research and support data-driven decision-making. They argue that "engagement in Citizen Science can educate and

empower young people through research by engaging the wider community in data collection, communication, and participation" [8]. In other words, CS serves not only as a learning tool, but also as a means for social and political participation that enables students to engage in global climate action [9].

Based on the explanation above, the literature suggests that the application of Citizen Science in science education has great potential to develop context-appropriate climate change literacy. Through real-life activities such as collecting environmental information, analyzing local phenomena, and thinking about global issues, students not only understand scientific concepts cognitively but also internalize the values of being critical, creative, and participatory environmental citizens. However, there is still a lack of research, especially in Indonesia, regarding how to implement CS-based learning models in a planned manner in science classes to improve climate change literacy among students.

Therefore, this study aims to analyze the role of Citizen Science in science learning as a pedagogical strategy that can link science in schools with the reality of climate change, while encouraging students to become agents of environmental change in the era of climate crisis.

## 2. Method

This study applies a Systematic Literature Review (SLR) design with reference to the PRISMA flow diagram guide as a reporting reference. The literature search process was conducted through various trusted databases, namely Scopus, Web of Science (WoS), ERIC, ScienceDirect, and SpringerLink, as well as Google Scholar as an addition. The search strategy used a combination of appropriate keywords, such as "Citizen Science", "Climate Change Literacy", and "Science Education", with Boolean operators (AND/OR) to obtain comprehensive results. The criteria used for inclusion were peer-reviewed articles published between 2020 and 2025, with an emphasis on the themes of science education (IPA) and climate change, and related to the concept of Citizen Science. Articles that did not meet the inclusion criteria, such as opinion pieces, non-scientific reports, or research not directly related to science learning and climate literacy, were excluded from the analysis.

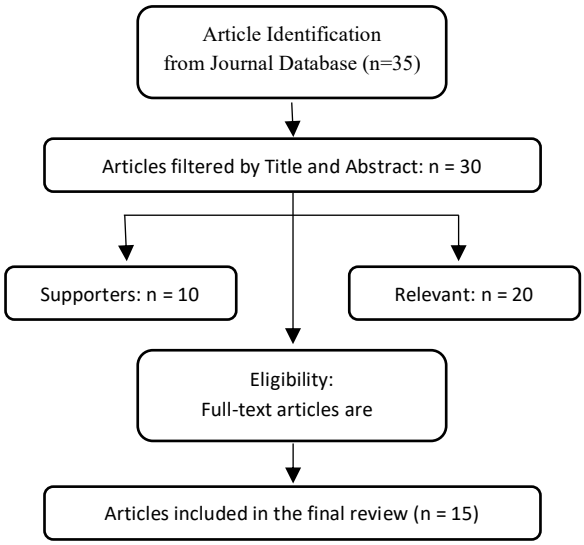


**Figure 1.** *PRISMA Flow Diagram Literature Review.*

The literature selection process was carried out in several stages, starting with screening based on the title and abstract, then continuing to the eligibility stage through a comprehensive text review, and ending with the inclusion stage, which was illustrated using a PRISMA flow diagram. The selected articles were then extracted into a table that included important information such as the author's name, year of publication, the research method used, and the reported research results. The collected data were analyzed using a narrative synthesis approach and with thematic analysis to identify patterns, topics, and relationships between studies.

## 3. Results and Discussion

### 3.1. Results

To gain a comprehensive understanding of the contribution of citizen science to climate and science education, we analyzed 15 relevant articles. The results of this literature review are presented in Table 1 below, which includes the author's identity, year of publication, research methods, and key findings of each study.

**Table 1.** *Results of the Article Review*

| Writer | Publication Year | Method | Research result |
|---|---|---|---|
| [4] | 2021 | Case study (pre-post survey) | The integration of Citizen Science into university classes (iNaturalist) led to increased interest in science, a love of nature, confidence in taking environmental action, and confidence in learning science. The most significant impact was seen among non-science students, indicating that Citizen Science successfully reaches groups outside the science field. |
| [3] | 2025 | Quasi-experiment | Demonstrates a significant impact on the development of critical thinking skills (analysis, problem recognition, problem-solving strategies) and creative thinking skills (new ideas, alternative options, out-of-the-box thinking). MANOVA findings indicate significant differences compared to conventional teaching methods. |
| [6] | 2024 | Quantitative descriptive | The implementation of a biodiversity Citizen Science project in an eco-friendly school has proven successful in improving high school students' sustainability literacy. Ninety-three percent of students successfully passed the Minimum Completion Criteria: 19.5% were in the adequate category, 55.5% in the good category, and 18% in the excellent category. This demonstrates that Citizen Science can effectively strengthen attitudes, understanding, and skills related to sustainability and relevant to climate change issues. |
| [10] | 2024 | **Systematic review** (100 empirical studies of CCS) | The analysis results show that Community & Citizen Science (CCS) makes a significant contribution to environmental education outcomes. Participants (adults & students) experienced improvements in scientific understanding (56 studies), inquiry skills (32), positive attitudes towards science and the environment (16), and self-confidence (11). In addition, there was an increase in environmentally friendly behavior (29) and a sense of community engagement (30). CCS that involve active participation (such as data analysis and reporting) tend to produce more significant learning effects. |
| [11] | 2025 | **Meta-analysis** (53 climate education studies) | A meta-analysis showed that climate change education (CCE) has a significant impact on various aspects of climate literacy. Knowledge levels increased with a large impact (g=0.77), attitudes toward climate change showed a moderate impact (g=0.39), and environmentally friendly behaviors increased with a small to moderate impact (g=0.36). This effectiveness was influenced by program duration, instructor quality, and learning materials. This study emphasizes the importance of a more in-depth and consistent climate change learning design. |
| [12] | 2022 | **Curriculum design study & project implementation** | Demonstrates that project-based STEM education focused on local climate issues (such as air pollution, urban heat islands, flooding, and renewable energy sources) can increase student participation, deepen their understanding of climate concepts, improve data analysis and systemic thinking skills, and foster a sense of stewardship for the environment and communities around them. Teachers report increased cross-disciplinary collaboration and increased student ownership of the learning process. |
| [13] | 2024 | **Qualitative dissertation** (interviews, surveys, observations) | A study of two CS projects (Illinois Butterfly Monitoring Network & CoCoRaHS) revealed that students and the community developed new understandings of scientific skills. Citizen Science enabled students to feel like part of the scientific process, not just participants. The research also emphasized how Citizen Science can serve as a means of communicating climate change issues, connecting science, policy, and society. The results suggest that CS can narrow the gap between "experts" and "non-experts" in science. |
| [14] | 2024 | **Survey & analysis of high school students' understanding** (Indonesian) | Research results show that Indonesian high school students' understanding of Citizen Science varies. Some students understand the basic concepts of Citizen Science and its relationship to scientific research, but many still view it as merely a voluntary activity. The study concluded that Citizen Science has significant potential to enhance climate awareness and contextual science learning if implemented in a structured manner within the school curriculum. |

| | | | |
|---|---|---|---|
| [12] | 2022 | Interviews with 31 children & adolescents (7–20 yrs) using iNaturalist | Children and adolescents' participation in the online CCS (iNaturalist) and field activities promotes science learning: improving scientific skills, knowledge of biodiversity, and skills in collecting and analyzing data. Research shows that CCS can be inclusive for adolescents with limited science experience, boosting their confidence, and increasing their interest in science. |
| [15] | 2020 | Quasi-experimental, pre-post questionnaire on 83 high school students (14–15 yrs) | Integrating Citizen Science projects into the formal science curriculum increases students' positive views of science and technology, enhances their understanding of the scientific process (scientific literacy), and fosters awareness of the Sustainable Development Goals (SDGs). Research shows that CS can strengthen the conceptual, procedural, and affective aspects of scientific literacy. |
| [16] | 2025 | Scoping review (60 articles) with supply-use-outcome model | Identifying 65 supporting and inhibiting factors for the implementation of Citizen Science in junior high and senior high school science classes. Supporting factors include curriculum-aligned project design, teacher support, and scientist participation. Barriers include time constraints, lack of teacher training, and unclear contributions to learning objectives. Overall, there are more supporting factors than barriers, suggesting that Citizen Science has significant potential in formal education. |
| [17] | 2025 | Systematic review (17 articles, last 5 years) | This study demonstrates that integrating climate change as a Socio-Scientific Issue (SSI) into science education can improve students' argumentation skills, scientific literacy, environmental awareness, and ethical decision-making skills regarding climate issues. SSI methods combined with STEAM, PBL, or digital technology have proven successful, but a major challenge is the lack of training teachers receive to teach this topic. |
| [18] | 2024 | Case studies & pre–post surveys | Students have a good understanding of the facts about the effects of climate change, but they are less able to understand the complex and long-term relationships. Over 90% of students believe that everyone can contribute and demonstrate positive attitudes toward climate protection efforts. However, concrete actions such as engaging their families or choosing environmentally friendly products are still minimal. Learning interventions have yielded only small, if not significant, improvements. |
| [19] | 2025 | Policy analysis | This study demonstrates that climate change has a direct impact on access to basic education, particularly in countries of the Global South. It emphasizes the importance of incorporating climate literacy into curricula, using experiential learning approaches, and policy measures that include teacher training and equitable resource provision to reduce socioeconomic inequalities. |
| [20] | 2025 | Scoping review | This review describes studies on climate education from 2022 to 2024 and proposes a planetary-consciousness pedagogy. The research findings demonstrate the need to connect science with ethical, emotional, and social aspects to foster awareness of planetary interdependence. This approach is considered crucial for enhancing the effectiveness of basic science education related to climate issues. |

A review of 15 articles indicates that integrating citizen science (CS) into science and physics learning has a positive impact on cognitive, emotional, and behavioral aspects. Several studies have shown improvements in scientific literacy, critical and creative thinking skills, and understanding of sustainability literacy. While CS has also been shown to foster positive attitudes toward the environment, concrete behavioral changes are still limited. On the other hand, several studies have identified supporting factors such as teacher involvement and curriculum-aligned project design, as well as constraints such as limited time and lack of teacher training.

## 3.2. Discussion

A literature review of 15 articles shows that the integration of Citizen Science (CS) in climate education plays a significant role in the development of students' cognitive, emotional, and behavioral aspects. From a cognitive perspective, most studies consistently show that CS can strengthen scientific understanding and scientific literacy. Student participation in CS projects, whether through digital applications such as iNaturalist or field projects related to biodiversity, can increase interest in science and also understanding of the scientific process [4][14][15]. This finding is supported by a meta-analysis that noted a significant increase in knowledge about climate change [11]. These results indicate that learning based on active participation and scientific practice provides students with a more authentic learning experience compared to conventional methods.

In terms of higher-order thinking skills, it is indicated that CS not only increases factual knowledge, but also enriches critical and creative thinking skills, as well as argumentation skills [3][17]. The integration of climate change issues as a Socio-Scientific issue (SSI) has been shown to expand the space for scientific discussion, train ethical decision-making skills, and encourage students to think systematically. In terms of affective and attitudinal aspects, CS fosters a positive view of science, increases self-confidence, and strengthens students' connections with their communities [10][12][13]. Students not only feel like participants, but also as part of the actual scientific process. This aspect is very important in climate-related education, because behavioral change often begins with self-awareness and identity as empowered individuals.

However, this study also shows a gap between views and actual actions. Although students have positive views on climate change issues, daily actions such as environmentally friendly consumption or family advocacy are still relatively low [18]. This finding is in line with the results of meta-analyses that show that improvements in knowledge and attitudes are significantly more significant than changes in behavior [11]. These results emphasize the need for educational approaches that not only raise awareness but also create long-term interventions based on concrete actions in schools and communities.

From an implementation perspective, factors that support and hinder the implementation of Citizen Science (CS) in formal education [16][14]. Identified supporting factors include support from teachers, project design aligned with the curriculum, and involvement from scientists. On the other hand, the main obstacles that often arise are limited time for learning, lack of training for teachers, and a lack of clarity regarding how CS contributes to achieving curriculum objectives. Meanwhile, incorporating local climate issues through project-based learning methods, such as air pollution or the urban heat island phenomenon, can increase student engagement and connect learning to the realities they face [12].

In terms of pedagogical development direction, recent literature highlights the importance of a more transdisciplinary approach, the notion of planetary consciousness that links science with ethical, emotional, and social aspects [20]. On the other hand, there are many benefits from integrating SSI based on digital technology. The implications of these findings indicate the need for more in-depth, participatory climate learning designs that address aspects of planetary consciousness and social justice [17][19].

Overall, this research demonstrates that Citizen Science not only enriches students' scientific understanding but can also serve as a comprehensive approach to climate education. However, its effectiveness depends heavily on factors such as curriculum design, teacher support, community engagement, and program sustainability. Therefore, future research and practice need to focus on long-term integration, strengthening teacher capacity, and cross-disciplinary collaboration to ensure that Citizen Science can truly drive transformation in pro-environmental knowledge, attitudes, and behaviors.

## 4. Conclusion

This literature review demonstrates that the integration of Citizen Science (CS) into science instruction plays a significant role in improving students' scientific literacy, climate literacy, and 21st-century skills. Cognitively, CS has been shown to deepen students' understanding of scientific concepts, enhance critical thinking skills, and enhance creativity through direct participation in data collection and analysis. Affectively, CS fosters positive attitudes toward science, provides increased self-confidence, and connects students with the environment and the scientific community. Behaviorally, although visible changes are still limited, involvement in CS projects fosters early awareness and commitment to environmentally friendly actions.

However, the implementation of CS in formal education still faces several obstacles, such as limited time, lack of teacher training, and the dilemma between teaching objectives and the contribution of scientific data. Therefore, CS's effectiveness will be maximized if supported by an integrated curriculum, adequate teacher training, and interdisciplinary collaboration. Overall, this study confirms that Citizen Science has the potential to be a transformative, contextual, and participatory pedagogical strategy in preparing a young generation with scientific literacy skills, environmental awareness, and readiness to become agents of change in facing the challenges of the global climate crisis.

## References


[1] M. G. Muluneh, "Impact of climate change on biodiversity and food security: a global perspective—a review article," *Agric. Food Secur.*, vol. 10, no. 1, pp. 1–25, 2021, doi: 10.1186/s40066-021-00318-5.

[2] D. Hadjichambi, A. C. Hadjichambis, A. Adamou, and Y. Georgiou, "A systematic literature review of K-12 environmental Citizen Science (CS) initiatives: Unveiling the CS pedagogical and participatory aspects contributing to students' environmental citizenship," *Educ. Res. Rev.*, vol. 39, p. 100525, 2023, doi: 10.1016/j.edurev.2023.100525.

[3] Adnan, S. Saenab, Rahmatullah, R. Almunawarah, and S. Sahira, "The Effect of Citizen Science Project Learning Model on Students' Critical and Creative Thinking Skills," *Int. J. Cogn. Res. Sci. Eng. Educ.*, vol. 13, no. 1, pp. 51–61, 2025, doi: 10.23947/2334-8496-2025-13-1-51-61.

[4] H. Smith *et al.*, "Leveraging Citizen Science in a College Classroom to Build Interest and Efficacy for Science and the Environment," *Citiz. Sci. Theory Pract.*, vol. 6, no. 1, pp. 1–13, 2021, doi: 10.5334/CSTP.434.
[5] A. S. Utami, I. Kaniawati, and S. Sriyati, *Citizen Science: Fostering Creative Thinking in Environmental Education*. in Vol. 1. Atlantis Press SARL, 2023. doi: 10.2991/978-2-38476-052-7_29.
[6] N. Hamidah, T. Hidayat, S. Sriyati, and T. Hadibarata, "Assessing Sustainability Literacy in Green School through Citizen Science Project on Biodiversity Learning," *J. Inov. Pendidik. IPA*, vol. 10, no. 2, pp. 150–159, 2024, doi: 10.21831/jipi.v10i2.71283.
[7] J. Roche *et al.*, "Citizen Science, Education, and Learning: Challenges and Opportunities," *Front. Sociol.*, vol. 5, pp. 1–10, 2020, doi: 10.3389/fsoc.2020.613814.
[8] M. Aczel and K. E. Makuch, "Climate change, young people, and the IPCC: The role of citizen science," *Elementa*, vol. 11, no. 1, pp. 1–13, 2023, doi: 10.1525/elementa.2022.00029.
[9] C. Flanagan, E. Gallay, and A. Pykett, "Urban youth and the environmental commons: rejuvenating civic engagement through civic science," *J. Youth Stud.*, vol. 25, no. 6, pp. 692–708, 2022, doi: 10.1080/13676261.2021.1994132.
[10] H. L. Ballard, A. J. Lindell, and C. C. Jadallah, "Environmental education outcomes of community and citizen science: a systematic review of empirical research," *Environ. Educ. Res.*, vol. 30, no. 6, pp. 1007–1040, 2024, doi: 10.1080/13504622.2024.2348702.
[11] V. M. J. Aeschbach, M. Schwichow, and W. Rieß, "Effectiveness of climate change education—a meta-analysis," *Front. Educ.*, vol. 10, no. May, 2025, doi: 10.3389/feduc.2025.1563816.
[12] M. Olateju and D. Frempong, "Sustainability-Driven Stem Education : A Project-Based Model for Teaching Climate Science In Urban High Schools," vol. 5, no. 4, pp. 125–164, 2022.
[13] W. Amananti, "Anyone Can Be A Scientist": Constructions Of Expertise And Citizenship In Citizen Science Literate Activity," vol. 4, no. 02, pp. 7823–7830, 2024.
[14] U. A. Gusti, N. Hamidah, T. Hidayat, and ..., "Analysis of Senior High School Students' Understanding on Citizen Science Project in Indonesia," … *Conf. Relig.* …, no. March, 2024.
[15] M. Á. Queiruga-Dios, E. López-Iñesta, M. Diez-Ojeda, M. C. Sáiz-Manzanares, and J. B. V. Dorrío, "Citizen science for scientific literacy and the attainment of sustainable development goals in formal education," *Sustain. Switz.*, vol. 12, no. 10, 2020, doi: 10.3390/su12104283.
[16] M. Müller, V. van den Bogaert, M. Foss-Jähn, P. Klein, J. Lorke, and T. Bruckermann, "What factors affect the implementation of citizen science in secondary school science classrooms? A scoping review," *Int. J. Sci. Educ. Part B Commun. Public Engagem.*, vol. 8455, pp. 1–20, 2025, doi: 10.1080/21548455.2025.2462797.
[17] Z. Chaniotou, C. Bardi, and M. Georgiou, "Climate Change as a Socio-Scientific Issue in Science Education - a Systematic Review," *APEduC Rev.*, vol. 6, no. 1, pp. 73–85, 2025.
[18] E. Feldbacher, M. Waberer, L. Campostrini, and G. Weigelhofer, "Identifying gaps in climate change education - a case study in Austrian schools," *Int. Res. Geogr. Environ. Educ.*, vol. 33, no. 2, pp. 109–124, 2024, doi: 10.1080/10382046.2023.2214042.
[19] D. Poimenidis, G. Ioannidou, and S. Poimenidou, "Abbreviated Key Title : ISRG J Edu Humanit Lit Bridging Climate Science and Literacy Education : Policy and Pedagogical Strategies for Primary Schools PhD , University of the Aegean , Greece crisis Literacy in Addressing Climate," vol. 2544, pp. 1–9, 2025, doi: 10.5281/zenodo.15795889.
[20] A. Strachan and A. Markwick, *Using a scoping review to inform a planetary-conscious pedagogical approach to primary science education*, vol. 55, no. 4. Springer Netherlands, 2025. doi: 10.1007/s11165-025-10280-y.