# Enhancing Students' Climate Change Literacy through Climate-Integrated Physics Learning via Citizen Science

**Diyah Ayu Kuntari, Sigit Ristanto, Joko Siswanto***
Physics Education Study Program, Universitas PGRI Semarang, Indonesia
*Corresponding Author: jokosiswanto@upgris.ac.id

**Received**: 2nd May 2025; **Accepted**: 28th July 2025; **Published**: 30th July 2025
DOI: https://dx.doi.org/10.29303/jpft.v11i1a.8916

***Abstract -*** *This study aims to evaluate the effectiveness of climate change-integrated physics learning using a citizen science approach in improving the Climate Change Literacy (CCL) of grade XI high school students. A quantitative research method with a one-group pretest-posttest design was employed. Data were collected through cluster random sampling using test instruments and observation sheets to monitor learning implementation and student participation. The analysis included normality, homogeneity, and paired t-tests to assess significant differences between pretest and posttest scores. The findings revealed significant improvements in students' CCL across cognitive, affective, and behavioral domains, with posttest scores showing statistically significant gains and 100% mastery achievement. This study provides empirical evidence supporting the integration of global issues into science education and offers valuable insights for curriculum development aimed at fostering climate awareness and literacy among youth.*

***Keywords***: *Physics Learning; Climate Change Literacy; Citizen Science; High School Students*

## INTRODUCTION

Climate change is a critical global challenge that demands urgent and coordinated attention from multiple stakeholders. Its impacts are already evident across many regions of the world, including Indonesia, through rising temperatures, shifting precipitation patterns, and an increasing frequency of extreme weather events (Rosalina et al., 2023: IPCC, 2023). Developing a comprehensive understanding of climate change is essential for the younger generation, who will serve as key agents of change in the future. Education plays a pivotal role in fostering awareness and understanding of climate-related issues. One effective strategy is to integrate climate change topics into the school curriculum, particularly within science subjects such as physics. As a discipline concerned with understanding natural phenomena and the principles of energy, physics provides a strong conceptual framework for exploring the causes and consequences of climate change (Rahmah, 2022).

Strengthening environmental education is essential to achieving the goals of sustainable development, as the future progress of a nation is largely determined by the younger generation who will inherit and lead it. A competent and responsible generation can only be cultivated through a high-quality and forward-looking education system. The advancement of a nation is unlikely to occur without significant development in the education sector. As a long-term and high-impact investment, education plays a critical role in shaping human capital and ensuring environmental sustainability (UNESCO, 2020).

This goal is particularly noble for the younger generation, as they will play a pivotal role in shaping the future and determining the progress of a nation (Muhardi, 2004). Students' limited understanding of climate change presents a significant challenge to sustainability and climate literacy. Many common misconceptions often unnoticed by both teachers and students relate to the distintion between weather and climate, as well as the variability of climate patterns across different regions of the world.

Youth people, as agents of change, must recognize the critical importance of protecting the earth's climate. In this context, understanding climate literacy is essential. According to UNESCO, literacy is a fundamental skill particularly cognitive skills in reading and writing that is independent of how, where, or from whom it is acquired (UNESCO, 2020). An individual's understanding of literacy is shaped by a veriety of factors, including scientific, institutional framework, ational context, cultural norms, and personal experience. In this regard, science teachers play a vital role in formal education by fostering environmental awareness and encouraging responsible attitudes toward sustainability among students. Environmental issues including climate change have increasingly been integrated into science curriculum around the world. Based on Rahmah's research (2022), science teachers can enhance students' understanding of climate change by contextualizing the topic students' everyday experiences and by fostering a sense of personal involvement in climate action. Encouragingly, many students are inclined to participate in environmentally friendly practices such as recycling, conserving energy, using public transportation, and choosing organic products which often require only small but meaningful lifestyle changes. These forms of behavioral engagement are essential in developing environmental literacy and promoting sustainable habits (UNESCO, 2020).

According to John Carroll in his book A Model of School Learning (as cited in Supardi, 2013), learning effectiveness is influenced by five factors: a). Attitude: Refers to students' dispositions toward learning, including motivation, interest, and active participation. b). Ability to Understand Instruction: Denotes students' cognitive ability to comprehend instructional content. c). Perseverance: The extent to which students persist and maintain effort throughout the learning process. d). Opportunity to Learn: The amount of time and access students have to engage with and master the material. e). Quality of Instruction: The degree to which teaching strategies are effective and tailored to students' needs. Effectiveness serves as a key indicator of success in the learning process. When appropriate instructional models or methods are applied, student learning outcomes tend to improve, thereby reflecting greater instructional effectiveness. The level of success can be seen from the achievement of student learning outcomes in individual and class completeness criteria (Gustria and Fauzi 2020). Through physics learning that integrates climate change issues, students are expected to understand the physics concepts underlying the phenomenon of climate change, such as the greenhouse effect, energy transfer, thermodynamics and literacy (Lestari et al., 2024). However, the implementation of physics learning integrated with climate change issues in schools in Indonesia is still experiencing various challenges. By considering this background, this study aims to examine how effective physics learning integrated with climate change issues through citizen science to improve students' CCL.

The issue of climate change is one of the biggest challenges of the 21st century, and public understanding of this issue is very important to encourage action. collective and appropriate policies. Climate change literacy is a competency that integrates knowledge, awareness, and the ability to act scientifically and responsibly towards climate change (Sato & Park, 2024; Matlack et al., 2023).

## RESEARCH METHODS

The method used in this research is quantitative research with pretest post test one group design. The research design of one group pretest posttest design is experimental research carried out only on one group that is randomly selected and without testing the stability and clarity of the state of the group before treatment is given (Susanti 2013). The subjects of this study were 64 11th grade high school students who were taking physics lessons on the topic of energy. The sampling technique used cluster rundom sempling. From the students of one school, 2 classes were taken randomly.

An observation sheet was used as the primary data collection instrument to document the implementation of the learning process, including student participation, and attitudes during the intervention. Students' performance was categorized as complete if they achieved at least a “good” score. Furthermore, when at least 85% of students obtained scores categorized as “good” or “very good,” the applied instructional method was considered effective (Sukmadinata 2009).

Climate literacy assessments were administered as both pretests and posttests to evaluate students’ knowledge and understanding before and after the instructional intervention. To assess the level of climate change literacy, researchers have developed a range of indicators that encompass cognitive, affective, and behavioral dimensions. Based on the literature review, climate change literacy indicators can be broken down into the following items:

**Table 1**. Indicators covering cognitive, affective, and behavioral dimensions

| | |
|---|---|
| Cognitive Domain (Sato & Park, 2024;Simpson et al., 2021) | Basic understanding of climate change (definition, causes and underlying mechanisms). Knowledge of anthropogenic factors (human activities such asuse of fossil fuels). Knowledge of the impacts of climate change on the environment and society. Knowledge of global mitigation policies and efforts (such as the Paris Agreement). |
| Affective Domain (Matlack et al., 2023; Wu & Otsuka, 2021) | Concern for the impacts of climate change. Perception of the severity of climate change. Trust in science as a source of climate change information. Readiness to support climate policies. |
| Behavioral Domain (Wu&Otsuka, 2021; Bhattacharya et al., 2018) | Readiness to change behavior to reduce carbon footprint (e.g., energy saving,recycling). Involvem ent in environmental campaigns or mitigation activities. Sustainable consumption and eco-lifestyle. Participation in environmental decision-making, including at the community level. |

A paired Sample t-test was conducted to examine the statistical significance of differences between students’ pretest and posttest scores. Additionally, the normalized gain (g) was calculated to measure the extent of improvement in students’ climate literacy. This gain score was categorized as low, medium, or high based on the criteria established which compares the actual gain with the maximum possible gain from pretest to posttest scores.

## RESULTS AND DISCUSSION

### Results

The test results and analysis of students' CCL are presented in tables 2, 3 and 4. Table 2 presents the results of Normality Test, Homogeneity Test, and Paired t-test of CCL of class A and class B students.

**Table 2.** Results of Normality Test, Homogeneity Test, and Paired t-test CCL

| Class | Test | ∑ | Min | Mak | R | SD | Normality p(α = 0.05) | Homogeneity p(α = 0.05) | T-test Paired (α = 0,05) |
|---|---|---|---|---|---|---|---|---|---|
| A | Pre | 30 | 45.24 | 61.71 | 55.04 | 3.75 | 0.106 | 0.102 | t = -34.61 p< 0.001 |
| | Post | 30 | 79.76 | 91.57 | 86.31 | 2.91 | 0.097 | | |
| B | Pre | 30 | 50.00 | 62.90 | 56.98 | 3.02 | 0.076 | 0.332 | t = -38.51 p< 0.001 |
| | Post | 30 | 80.95 | 90.67 | 86.47 | 2.41 | 0.151 | | |

Description: ∑ = number of students, Min = lowest score, Mak = highest score, R = mean, SD = standard deviation, p = p-value

Table 2 presents the result of the inferential statistical analysis used to assess the effectiveness of instruction in enhancing students' Climate Change Literacy (CCL) in two classes, A and B. Three statistical procedures were conducted: a normality test, a homogeneity test, and a paired sample t-test. a). The normality was performed to determine whether the data were normally distributed. The testresults showed p values > 0.05 across the pretest and posttest data in both classes (e.g, Class A pretest p = 0.106 and posttest p = 0.097), which means the data was normally distributed. This fulfills the basic assumption for the use of further parametric tests. b). Homogeneity Test This test is used to test whether the data variances of the two groups (pretest and post-test) are homogeneous. The results in Class A show p = 0.102 and in Class B p = 0.332, both of which are > 0.05. This means that the variance between data is considered homogeneous, so the analysis can continue with the paired t-test. c). This test is used to determine the significance of the difference between pretest and post-test scores. The results show a very large t value and p value <0.001 in both classes (t = -34.61 for Class A and t = -38.51 for Class B). These result indicate a statistically significant difference between the pretest and post-test scores, suggesting that the implemented instructional approach was effective in enhancing students' CCL.

Following data collection, the results were analyzed using appropriate statistical procedures to determine the impact of the intervention. The results of the analysis are presented in Table 3.

**Table 3.** Average score, Classical Completion and n-gain CCL

| Class | Pretest | | | Posttest | | | <g> | |
|---|---|---|---|---|---|---|---|---|
| | Average | Completeness | | Average | Completeness | | Score | Criteria |
| | | % | Ket | | % | Ket | | |
| A | 56.22 | 10 | Not Completed | 86.31 | 100 | Completed | 0.70 | High |
| B | 53.34 | 17 | Not Completed | 86.47 | 100 | Completed | 0.69 | Medium |

The findings indicatedthat physics instruction integrated with climate change contentthrough a citizen science approach was effective in enhancing the Climate Change Literacy (CCL) of grade XI high school students. This was evidenced by the substantial improvement in average test scores frompretest to posttest scores in Class

A (from 55.04 to 86.31; n-gain 0.70-high category) and Class B (from 56.98 to 86.47; n-gain 0.69-moderate category). Furthermore, the percentage of students meeting the mastery learning criteri increased dramatically from 10% and 17% to 100%, demonstrating that nearly all students achieved the established competency standard.

**Table 4**. Mean score, completeness, and n-gain for each CCL indicator

| Indicator | Class | Pretest | | | Posttest | | | <g> | |
|---|---|---|---|---|---|---|---|---|---|
| | | Average | Completeness | | Average | Completeness | | Score | Criteria |
| | | | % | Ket | | % | Ket | | |
| Cognitive Domain | A | 56.22 | 17 | Not Completed | 85.78 | 100 | Completed | 0.67 | Medium |
| | B | 53.34 | 3 | Not Completed | 84.57 | 100 | Completed | 0.66 | Medium |
| Affective Domain | A | 54.68 | 0 | Not Completed | 87.78 | 100 | Completed | 0.71 | High |
| | B | 60.34 | 30 | Not Completed | 87.44 | 100 | Completed | 0.68 | Medium |
| Behavioral Domain | A | 36.57 | 30 | Not Completed | 76.77 | 90 | Completed | 0.62 | Medium |
| | B | 40.00 | 43 | Not Completed | 80.00 | 100 | Completed | 0.66 | Medium |

Based on the analysis, significant improvements iwere observed across all three assessed domains: Knowledge (Cognitive Domain), Attitude and Risk Perception (Affective Domain), and Behavior and Participation (Behavioral Domain). In all areas, posttest scores surpassed pretest scores, indicating the effectiveness of the intervention.

For the Cognitive Domain, Class A's average score increased from 56.22 to 85.78 with an n-gain of 0.67 (medium category). Similarly class B improved from 53.34 to 84.57 with an n-gain of 0.66 (medium), demonstrating enhanced conceptual students' understanding of climate change. These results align with prior studies highlighting the role of targeted science instruction in improving environmental literacy (Gürbüz, 2024).

In the Affective Domain, Class A achieved the highest gain (g = 0.71), reflecting substantial growth in students' awareness and risk perception related to climate change. Class B also showed a positive outcome with a gain of 0.68 (moderate), suggesting an increase in emotional engagement with climate-related issues. These findings demonstrate the success of the instructional intervention in fostering environmental awareness among students.

The Behavioral Domain indicator showed a significant increase despite its low initial score. Class A increased from 36.57 to 76.77 (n-gain 0.62-medium), while Class B from 40.00 to 80.00 (n-gain 0.66-medium) so it can indicate that students not only understand the issue of climate change but also begin to show a tendency to behave environmentally friendly.

**Table 5.** Results of Cognitive Domain Knowledge Test

| Class | Pretest | | | Posttest | | | <g> | |
|---|---|---|---|---|---|---|---|---|
| | Average | Completeness | | Average | Completeness | | Score | Criteria |
| | | % | Ket | | % | Ket | | |
| A | 56.22 | 17 | Not Completed | 85.78 | 100 | Completed | 0.67 | Medium |
| B | 53.34 | 3 | Not Completed | 84.57 | 100 | Completed | 0.66 | Medium |

Table 5 shows the test results of a statistically significant improvement in the students' cognitive domain. This is because effective learning methods, active student involvement, and constructive feedback help improve students' understanding of climate change. This aspect can be explained in the context of cognitive theory which states that knowledge gained from learning can improve students' intellectual ability to understand and apply information (Matra and Lahmi 2024). In the context of climate change, students' knowledge not only includes aspects of basic facts (such as the definition of climate change or its causes), but also the ability to understand its consequences and possible solutions to reduce its negative effects (Barokah et al. 2024).

**Table 6.** Results of Affective Domain Questionnaire

| Class | Pretest | | | Posttest | | | <g> | |
|---|---|---|---|---|---|---|---|---|
| | Average | Completeness | | Average | Completeness | | Score | Criteria |
| | | % | Ket | | % | Ket | | |
| A | 54.68 | 0 | Not Completed | 87.78 | 100 | Completed | 0.71 | High |
| B | 60.34 | 30 | Not Completed | 87.44 | 100 | Completed | 0.68 | Medium |

Table 6 shows the results of the questionnaire measuring students' attitudes and risk perceptions related to climate change literacy showed a significant increase between the pretest and post-test. In class A, the average pretest score was 54.68 with 0% completeness, increasing to 87.78 with 100% completeness after learning. Likewise in class B, which increased from 60.34 with 30% completeness to 87.44 with 100% completeness. This increase shows that the learning has successfully influenced students' attitude in understanding the risks of climate change, so that they become more aware and concerned about this issue. In the context of the Affective Domain, which relates to feelings, attitudes, and risk perception, this finding is consistent with the results of research by Diquito et al. (2024), which showed that climate change education not only affects students' knowledge, but also shapes their attitudes and perceptions towards environmental issues.

**Table 7.** Results of Behavioral Domain Observation

| Class | Pretest | | | Posttest | | | <g> | |
|---|---|---|---|---|---|---|---|---|
| | Average | Completeness | | Average | Completeness | | Score | Criteria |
| | | % | Ket | | % | Ket | | |
| A | 36.57 | 30 | Not Completed | 76.77 | 90 | Completed | 0.62 | Medium |
| B | 40.00 | 43 | Not Completed | 80.00 | 100 | Completed | 0.66 | Medium |

Table 7 shows the results of observation of behavior and participation In class A, the average pretest score was 36.57 with 30% completeness, which increased to 76.77 with 90% completeness after learning. In class B, the average pretest score was 40.00 with 43% completeness, which increased to 80.00 with 100% completeness. This increase shows that the applied learning successfully changed students' behavior to be more active and concerned about climate change, as well as increased their participation in environment-related activities. According to Jenkins and Fielder (2021), effective climate change education not only increases students' knowledge, but also contributes to changes in their behavior, encouraging them to engage more actively in climate change mitigation efforts.

**Discussion**

Based on the data presented in the table, the following section discusses the result of the paired t-test and gain per class. Class A Paired t-test in class A, the paired t-test results show a t-value of -34.61 with a very low p-value (<0.001). This p-value is lower than the significance level $\alpha = 0.05$, the result indicates a statistically significant difference between the pretest and posttest scores. This suggests that the instructional intervention had a strong impact on improving students' Climate Change Literacy (CCL) in Class A. In summary, the observed differences between pretest and posttest scores suggest that the instructional intervention had a substantial effect on student learning outcomes. This indicates that the applied, teaching strategies and the learning materials contributed significant to enhancing students' competencies.

Gain per Class: Gain is the average difference between posttest and pretest scores divided by the difference between the maximum and minimum scores on the pre-test. To calculate the gain per class A:

$$\text{Gain} = \frac{\text{Average Posttest} - \text{Average Pretest}}{\text{Maximum Value} - \text{Minimum Value}} \quad (1)$$

From the data given: Pretest Mean = 55.04 Posttest Mean = 86.31 Pretest Maximum Value = 61.71 Pretest Minimum Value = 45.24 Then, the Gain for class A is:

$$\text{Gain} = \frac{86.31 - 55.04}{61.71 - 45.24} = \frac{31.27}{16.47} \approx 1.90$$

This gain shows a statistically significant increase in student learning outcomes in class A after being given the treatment. Class B Paired t-test: The results of the paired t-test for class B showed a value of t = -38.51 with a p-value < 0.001. The very small p-value ($p < 0.001$) also indicates a statistically significant difference between the pretest and posttest scores in class B. This indicates that the treatment given to class A after the treatment was given. This indicates that the treatment given between the pretest and posttest also had a significant effect on improving student learning outcomes. The intervention conducted in class B succeeded in significantly improving student learning outcomes. Gain per Class: As in class A, the gain for class B can be calculated using the same formula. Based on the available data: Pretest Mean = 56.98 Posttest Mean = 86.47 Pretest Maximum Value = 62.90 Pretest Minimum Value = 50.00 Then, the Gain for class B is:

$$\text{Gain} = \frac{86.47 - 56.98}{62.90 - 50.00} = \frac{29.49}{12.99} \approx 2.29$$

The gain for class B indicated a considerable improvement in students' learning outcomes following the intervention. CCL among students was measured using three key indicators: cognitive (knowledge), affective (attitudes and risk perception), and behavioral (behavior and participation) dimensions. The results revealed a significant improvement across all indicators after instruction and enhanced exposure to climate change-related content.

The discussion of the results of this measurement will be explained based on these three aspects. The Cognitive (Knowledge) aspect of this indicator aims to assess students' knowledge of climate change, including their understanding of the causes, effects, and mitigation efforts of climate change (Eva Monalisa et al. 2023).

Based on the results of the pretest and posttest, there was a significant increase in students' understanding of this topic. In class A, the pretest results showed an average score of 56.22 with a percentage of completeness of 17%, which indicated that most students had not mastered the climate change material well. However, after the lesson, the posttest results showed that the average score increased significantly to 85.78 with a 100% pass rate. This score increase exceeded 29 points, indicating that the effectiveness of the learning method significantly expanded the knowledge of class A students on climate change. Meanwhile, in class B, although the pretest results showed a lower average score of 53.34 with only 3% completion, after the learning process, the posttest showed the average score increased to 84.57 with 100% completion. This shows that although the initial achievement was very low, the learning process was able to significantly improve the knowledge of class B students, with an increase of more than 31 points. Both classes, A and B, showed satisfactory results even though class B initially had a lower completeness on the pre-test, but managed to achieve completeness. 100% on the post-test. This shows the success of the teaching method in improving students' understanding of climate change effectively.

The Attitude and Risk Perception (Affective) dimension assesses students' perceptions and attitudes towordclimate change risks, including the extent to which they feel personally affected and their perspectives on possible mitigation measures. Pretest and post-test results revealed a statistically significant improvement in students' affective responses toward climate change.

In class A, the pretest results showed an average score of 54.68 with a 0% completion rate, meaning that no students had a comprehensive attitude and understanding of climate change risks at first. However, after the learning process, the posttest results showed significant progress, with the average score reaching 87.78 and 100% completion rate. All students in class A showed a better understanding and a more positive attitude towards climate change issues. This improvement showed a significant change in their views on the importance of the issue and the mitigation measures to be taken. Meanwhile, in class B, although the pretest average score reached 60.34 with a 30% completion rate, indicating that some students already had a basic understanding of the issue, they still did not fully understand the risks and impacts. However, after the learning process, the posttest results showed an excellent improvement. The average posttest score was 87.44 with 100% completion rate. All students in class B achieved a high level of completion, illustrating a very positive attitude towards climate change. While many students did not fully realize the significance of this issue at first, after learning about it, they better understood the risks and effects of climate change. Class A and B each showed significant progress in their attitudes towards climate change, with students who were previously less familiar with the issue becoming more aware of its risks and impacts after the learning process.

This aspect avaluates the extent of students engagement in tangible actions related to climate change mitigation, such as participating in programs that contribute directly to environmental preservation (Adinata and Setiawan, 2024). Pretest and posttestresults indicated a significantimprovement in students' behavior and participation regarding to climate change related actions.

In class A, the pretest results showed an average score of 36.57 with a completion rate of only 30%, indicating that many students had not participated in activities related to climate change issues. However, after the learning process, the posttest results showed a significant improvement, with the average score rising to 76.77 and 90% completeness. This shows that almost all students in class A have successfully engaged in activities that support environmental conservation, with scores increasing by more than 40 points. This increase reflects a rapid development in their behavior and engagement with climate change efforts. Meanwhile, in class B, although the initial completion rate on the pretest was only 43%, with an average score of 40.00, the learning successfully increased student participation significantly. After the learning, the posttest results showed impressive progress, with the average score reaching 80.00 and 100% completion criteria. This shows that despite the low initial achievement for class B, almost all students managed to engage in activities related to climate change and actively participate in the issue.

Overall, the findings indicate that climate change-oriented education enhances students' engagement in cocrete environment preservation actions. Although students exhibited varying levels of participation during the pre-test, all demonstrated substantial improvement in the post-test phase. This nstructional approach has not only enhanced students' knowledge and awareness, but also encourages them to be actively involved in environmental conservation efforts. Measuring of climate change literacy in 11th grade high school students in Semarang City showed encouraging results, with significant improvements in each indicator-knowledge, attitude, and participation-after the learning process.

These findings are supported by Bhattacharya et al. (2018), who found that incorporating climate change issues into science educational effectively enhances students' environmental knowledge and awareness from an early age. They emphasized the importance of an interdisciplinary and contextual approach in developing comprehensive climate literacy, which encompasses cognitive, affective, and behavioral dimensions. Similar conclusions were drawn by Wu and Otsuka (2021), who reported that participatory approaches in climate change education can enhance students' engagement in mitigation actions. These include reducing carbon emissions and adopting sustainable lifestyles practices. Thus, climate change–based physics instruction has been shown to be highly effective not only in enhancing conceptual understanding, but also in shaping students' pro-environmental attitudes and behaviors (Sartika et al., 2023). This research contributes to the development of a global issue-based learning model that supports the goals of sustainable education and is relevant to be widely applied.

Research by (Wiryanto et al. 2023) on the use of STEM-based modules in physics learning integrated with climate change issues also showed a significant increase in students' environmental literacy. The module was designed to improve students' knowledge and attitudes towards climate change through experiments involving observation and data collection, which is relevant to the concept of citizen science in this study (Wiryanto et al. 2023). In addition, (Granato, Campera, and Bulbert 2025) also stated that active learning involving global issues such as climate change can increase students' awareness and motivation to care more about environmental issues. They found that students involved in projects based on direct observation of environmental issues showed a significant improvement in their attitude and participation in learning activities.

Although improvements were observed in the behavioral and participation domains, the findings suggest that the learning intervention still had limited influence on actual behavior change. While student engagement increased, there remains room to strengthen its impact on daily actions. This aligns with findings by Fasya, Wiranti, and Hamidaturrohmah (2024) who noted that student involvement in community-based projects such as citizen science can enhance active participation. However, they also emphasized the need for additional scaffolding and motivation to encourage more proactive behaviors in daily life. These findings are further supported by prior studies demonstrating that environmental issue-based learning enhances both students' conceptual understanding and engagement (Feser et al., 2023).

According to Adolph (2024), the application of a directed physics learning model on the topic of climate change can enhance students' critical thinking skills and responsiveness to the environment issues. Previous studies have shown that this approach effective increasing students' environmental awareness and conceptual understanding of climate change. Students' science literacy skills, particularly regarding the topic of global warming. Although not directly related to citizen science, this study offers valeable insights into students' science literacy levels, which can serve as a foundation for designing more effective instructional interventions (Wicaksana and Rachman 2018). Future research could explore the effectiveness of this approach in a digital format or at different education levels to broaden its impact and applicability

## CONCLUSION

Based on the results of the study, physics learning integrated with climate change issues with a citizen science approach proved effective in improving the Climate Change Literacy (CCL) of grade XI high school students, including cognitive, affective, and behavioral domains. Significant increase in pretest to posttest scores and classical completeness that reached 100% showed the success of the intervention. The n-gain score was in the moderate to high category, with the affective domain showing the highest improvement, signifies the effectiveness of this approach in shaping students' environmental awareness and concern. The contribution of this research lies in strengthening global issue-based learning that is contextual and relevant, and encourages active involvement of students as agents of change. The practical implication is the importance of integrating climate change issues in the science curriculum to create a generation that is responsive to environmental challenges. For future research, similar development models with more subjects and education levels as well as testing in the context of digital or hybrid learning are suggested.

## REFERENCES

Adinata, T. & Setiawan, J.B. (2024). Peran Pembelajaran Berbasis Lingkungan dalam Menumbuhkan Kesadaran Konservasi pada Siswa. *Jurnal Cakrawala Pendidikan Dan Biologi*, *1*(3), 35–40. https://doi.org/10.61132/jucapenbi.v1i3.184

Adolph, R. (2024). Pembelajaran materi perubahan iklim dengan model guided inquiry menggunakan pendekatan socio scientific issues (SSI) untuk meningkatkan keterampilan berpikir kritis peserta didik SMA. 03(01), 1–23.

Arifin, H. N., & Ismail, S. N. (2022). Komparasi Efektivitas Pembelajaran Daring dan Luring MA Al-Amin Tahun Pelajaran 2021/2022. *Widya Balina*, *7*(2), 446–461. https://doi.org/10.53958/wb.v7i2.151

Barokah, A., Hayuningtyas, A. L., Fazriah, I. L., & Nazah, S. (2024). Menganalisis proses belajar dan pembelajaran dalam teori kognitif pada peserta didik di sekolah dasar. Edukatif: *Jurnal Ilmu Pendidikan*, 6(3), 2490–2497.

Bhattacharya, D., Forbes, C. T., Chandler, M. A., Steward, K. C., & Sutter, A. M. (2018). Climate literacy: Insights from research on K-16 climate education. *Green Schools Catalyst Quarterly*, 5(4), 26–37.

Diquito, T. J. A., Acuña, A. R., Garcia, J. R., & Laganson, J. B. C. (2024). Analysis of Students' Climate Change Learning Using the Affective Domain of Learning. *Revista De Gestão - RGSA*, *18*(6), e05908. https://doi.org/10.24857/rgsa.v18n6-075

Fasya, N. A., Wiranti, D. A., & Hamidaturrohmah, H. (2024). Efektivitas Model Project Citizen untuk Meningkatkan Kemampuan Literasi Budaya Peserta Didik pada Pembelajaran Pendidikan Pancasila Kelas 5 SDN 2 Tahunan. *Jurnal Pendidikan Dan Pembelajaran Indonesia (JPPI)*, *4*(3), 930–942. https://doi.org/10.53299/jppi.v4i3.667

Feser, M. S., Haak, I., & Rabe, T. (2023). VeSP-Be – Vergleich von Studieneingangsphasen in Physik hinsichtlich des Sense of Belonging von Studierenden. *Dokumentation der Erhebungsinstrumente und deren deskriptive, quantitative Ergebnisse.* 46. DOI: https://doi.org/10.25656/01:26178

Granato, C., Campera, M., & Bulbert, M. (2025). Active Learning Affects Children's Intention to Act and Awareness of the Importance of Nature and Understanding Environmental Change. *World*, *6*(2), 36. https://doi.org/10.3390/world6020036

Gürbüz, E. (2024). *Middle School Students' Misconceptions and Attitudes Toward Climate Change* [M.S. - Master of Science]. Middle East Technical University.

Gustria, A., & Fauzi, A. (2020). Efektivitas e-modul pembelajaran fisika berbasis STEM education terintegrasi materi perubahan iklim terhadap kompetensi peserta didik. *Jurnal Pendidikan Fisika,* 9(2), 105–111.

Lestari, N. A., Susanti, F. M., Deta, U. A., Hariyono, E., & Madlazim, M. (2024). Climate Change Education in Sustainable Physics Learning: Systematic Literature Review. In *E3S Web of Conferences* (Vol. 482, p. 04003). EDP Sciences.

IPCC. (2023). IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. 35–115. https://doi.org/10.59327/IPCC/AR6-9789291691647

Matlack, M., Covert, H., Shankar, A., Zijlmans, W., Wahid, F. A., Hindori-Mohangoo, A., & Lichtveld, M. (2023). Development of a pilot literacy scale to assess knowledge, attitudes, and behaviors towards climate change and infectious disease dynamics in Suriname. *International Journal of Environmental Research and Public Health*, 20(24), 7178.

https://doi.org/10.3390/ijerph20247178

Matra, E., & Lahmi, A. (2024). Teori belajar kognitif (Gambaran umum teori kognitif dan implikasi teori belajar kognitif). *Jurnal Multidisiplin Inovatif*, 8(7), 2246–6110.

Eva Monalisa Vebry Kusuma, Gunawan Santoso, Solehun, & Baiq Dina Erika Wardiningtias. (2023). Pengaruh Pembelajaran Berbasis Proyek Terhadap Kesadaran Lingkungan Sekolah dan Keluarga Untuk Meningkatkan Ketakwaan Kepada Tuhan YME dan Berakhlak Mulia Di Kelas 1. *Jurnal Pendidikan Transformatif*, *2*(4), 289–309. https://doi.org/10.9000/jpt.v2i4.639

Muhardi, M. (2004). Kontribusi Pendidikan dalam Meningkatkan Kualitas Bangsa Indonesia. *MIMBAR : Jurnal Sosial dan Pembangunan, 20*(4), 478-492. doi:https://doi.org/10.29313/mimbar.v20i4.153

Rahmah, D. M. (2022). Perubahan iklim dalam pendidikan IPA berkelanjutan. Jurnal Sains Edukatika Indonesia, 4(2), 20–25. https://jurnal.uns.ac.id/jsei/article/view/70940

Rosalina, D., Idris, I., Mulyani, G., Deselia, S., & Pangestu, G. (2023). Navigasi Isu Perubahan Iklim di Pemilu 2024: Panduan Komunikasi untuk Politisi. *Monash Climate Change Communication Research Hub Indonesia Node, Monash University, Indonesia*.

Sartika, S. B., Supriyadi, S., & Wiguna, A. (2023). Modul Elektronik Berbasis Android Materi Perubahan Iklim Terintegrasi Nilai-nilai Islam. *Edukasi Islami: Jurnal Pendidikan Islam*, *12*(04).

Sato, F. E., & Park, J. (2024). A systematic review of climate change literacy assessment methods. *The Journal of Environmental Education,* 56(1), 65–83.https://doi.org/10.1080/00958964.2024.2385333

Simpson, N. P., Trisos, C. H., Krönke, M., & Andrews, T. (2021). Climate change literacy in Africa. *Nature Climate Change*, 11, 937–944. https://doi.org/10.1038/s41558-021-01171-x

Supardi, S. (2013). *Sekolah Efektif.* Jakarta: PT. Raja Grafindo.

Susanti, R. (2013). Penerapan pendekatan demonstrasi interaktif untuk meningkatkan pemahaman konsep fisika siswa SMA. Universitas Pendidikan Indonesia, 19–29. reprository.upi.edu.philosophical assessment.

UNESCO. (2020). Education for sustainable development: A philosophical assessment. In Impact (Issue 18). https://doi.org/10.1111/j.2048-416x.2009.tb00140.x

Wicaksana, A., & Rachman, T. (2018). Deskripsi kemampuan literasi sains siswa pada materi pemanasan global. Angewandte Chemie International Edition, 6(11), 951–952. 3(1), 10–27. https://medium.com/@arifwicaksanaa/pengertian-use-case-a7e576e1b6bf.

Wiryanto, W., Fauziddin, M., Suprayitno, S., & Budiyono, B. (2023). Systematic literature review: Implementasi STEAM di sekolah dasar kelas rendah. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, 7(2), 1545–1555.

Wu, J., & Otsuka, Y. (2021). Exploring the climate literacy of high school students for better climate change education. *International Journal of Global Warming*, 25(2), 151–168. https://doi.org/10.1504/IJGW.2021.112894