Empowering Students Through Real Actions and Local Wisdom: Integrating Climate Change Education for Sustainability

Saptono Nugrohadi
SMA Negeri 3 Salatiga, Jalan Kartini 34 Salatiga, 50711, Jawa Tengah Indonesia
e-mail: saptononmulang@gmail.com

Abstract: *This article explores the integration of climate change education into chemistry lessons at SMA Negeri 3 Salatiga. The objective is to enhance students' environmental awareness and encourage their active participation in sustainability initiatives. Methods include implementing project-based learning, practical experiments, and collaborative discussions. Results reveal increased student understanding of concepts like the carbon cycle, greenhouse effect, and air pollution through hands-on activities and interdisciplinary approaches. These findings highlight the critical role of chemistry education in fostering environmental responsibility among students.*

Key Words*:* climate change; chemistry education; sustainability; hands-on learning; environmental awareness

Introduction

Climate change has become one of the most pressing challenges of our time, influencing not only ecosystems but also economies and communities globally. For instance, the Intergovernmental Panel on Climate Change (IPCC) has reported that global temperatures have risen by 1.1°C above pre-industrial levels, causing more frequent and severe weather events. The Intergovernmental Panel on Climate Change (IPCC, 2023) reports that the Earth's average temperature has risen by 1.1°C above pre-industrial levels, leading to adverse effects such as rising sea levels and unpredictable weather patterns. In Indonesia, these impacts are felt acutely, with threats to agriculture, biodiversity, and coastal communities (Ministry of Environment and Forestry Indonesia, 2022).

In this context, education holds transformative power. By incorporating climate change into school curricula, educators can equip students with the knowledge and skills needed to address this issue. Chemistry, with its focus on processes like the carbon cycle, greenhouse effect, and pollution chemistry, provides an ideal framework for explaining climate change scientifically. This approach aligns with educational development priorities, as outlined by UNESCO (2021).

This study highlights how SMA Negeri 3 Salatiga integrates climate education into chemistry lessons, combining scientific theory, project-based learning, and local wisdom (Nugrohadi, 2016). Local wisdom in this context includes traditional water management practices, sustainable agricultural techniques, and cultural values that promote environmental stewardship. These practices not only enhance the relevance

of climate education but also provide students with culturally rooted solutions to environmental challenges. By fostering connections between these elements, students are empowered to understand and address environmental challenges effectively.

Method

This study employed a mixed-method approach to explore the effectiveness of integrating climate education into chemistry. Key elements include:

1. **Research Design**: Implementing project-based learning within chemistry lessons (Setyowati & Utami, 2018).
2. **Participants**: Students from SMA Negeri 3 Salatiga, spanning grades 10 to 12.
3. **Instruments**: Surveys, pre- and post-tests, and observation logs (Shelly, 2010).
4. **Procedures**:
    - Practical experiments, such as simulating the greenhouse effect and analyzing water quality (Rahmawati & Santoso, 2020).
    - Collaborative projects like tree planting and waste reduction campaigns (UNESCO, 2021).
    - Guided discussions linking theoretical knowledge to real-world applications.
5. **Analysis**: Comparing pre- and post-test scores to measure changes in understanding and awareness (Sparrow, 2010).

Results and Discussion

The integration of climate education into chemistry lessons at SMA Negeri 3 Salatiga has yielded significant outcomes, both in terms of student engagement and knowledge acquisition. This section highlights various aspects of the results, such as hands-on experiments, the application of local wisdom, collaborative projects, and measurable knowledge improvements.

Enhancing Awareness Through Experiments

One of the most impactful methods used in this program was the "Greenhouse Effect in a Plastic Bottle" experiment. This activity provided students with a tangible understanding of how greenhouse gases trap heat, simulating the Earth's atmosphere using simple materials like plastic bottles, soil, and clear wraps. Through this experiment, students not only observed temperature differences but also grasped the urgency of addressing global warming.

Beyond classroom experiments, the school’s greenhouse served as a practical learning site where students studied renewable energy technologies and sustainable

farming practices. This hands-on approach enriched their understanding and connected theoretical concepts to real-world applications.

Local Wisdom and Cultural Relevance

Incorporating local traditions and practices into lessons helped contextualize climate education. Students explored water management techniques and environmentally friendly agricultural practices rooted in their community's heritage. These efforts were complemented by recent innovations such as the adoption of solar panel technologies at the school, which further engaged students in renewable energy solutions and highlighted the importance of sustainable living.

Collaborative Efforts and Community Involvement

Collaborative projects were another cornerstone of this initiative. Students, parents, and local communities participated in activities such as tree planting, waste reduction campaigns, and eco-friendly product development. These initiatives fostered a sense of responsibility and strengthened community ties, demonstrating the power of collective action in addressing environmental challenges.

Tangible Improvements in Knowledge

Quantitative data from pre- and post-tests revealed substantial gains in students' understanding of climate-related concepts. The average score improvements across topics like the carbon cycle, air pollution, and sustainable solutions underscore the effectiveness of this integrated approach. These results reflect not just knowledge acquisition but also a shift toward environmentally conscious behavior.

By combining these elements, the program at SMA Negeri 3 Salatiga serves as a model for integrating climate education into chemistry, demonstrating the potential of education to inspire change and empower students to take active roles in sustainability efforts.

This section highlights the outcomes of integrating climate education into chemistry lessons, presenting insights from hands-on experiments, the role of local wisdom, collaborative projects, and measurable knowledge gains.

1. Hands-On Learning and Engagement

Students conducted experiments to observe how greenhouse gases trap heat. In the "Greenhouse Effect in a Plastic Bottle" activity, two plastic bottles were used, one covered with clear plastic wrap and the other left open. Both bottles were filled with soil and exposed to sunlight, with thermometers placed inside to measure temperature changes over time. This setup allowed students to visualize how the trapped heat in the covered bottle mimics the greenhouse effect in Earth's atmosphere. Table 1 shows the recorded temperature changes:

Table 1 Illustrates the temperature differences observed during the experiment:

Time	Data	
(Minutes)	Temperature (Bottle Covered)	Temperature (Bottle Oper
0	27°C	27°C
10	33°C	29°C
20	38°C	31°C
30	42°C	32°C

This experiment heightened students' awareness of the urgent need to reduce greenhouse gas emissions (Luria, 1969). Moreover, the greenhouse at SMA Negeri 3 Salatiga served as an educational space where students could study sustainable farming practices and renewable energy use, further enriching their learning experience (https://www.sman3sltg.sch.id/2024/05/greenhouse-sma-negeri-3-salatiga-tempat.html).

Figure 1. Students practicing sustainable composting

2. Leveraging Local Wisdom

Incorporating local practices, such as water conservation techniques and traditional farming methods, provided students with culturally relevant insights. Figure 1 highlights student perceptions on the importance of local wisdom in climate action. Additionally, SMA Negeri 3 Salatiga has implemented solar panel technology to engage students in renewable energy practices,as documented in recent initiatives. Most students (88%) acknowledged that preserving water resources is a vital climate mitigation strategy (Nugrohadi, 2016). (https://www.sman3sltg.sch.id/2023/10/teknologi-panel-surya-menarik-minat.html)

3. Collaborative Projects

Students partnered with parents and the community in tree-planting initiatives and clean-up drives. Additionally, SMA Negeri 3 Salatiga's Adiwiyata program emphasized student creativity in environmental conservation, as highlighted in activities like crafting eco-friendly products from waste materials (https://www.sman3sltg.sch.id/2022/04/kader-adiwiyata-smantisa-mengkreasi.html).

Figure 2. Students practicing sustainable composting

Furthermore, the school collaborated with PT Marimas to promote environmental education through initiatives such as waste management campaigns and green spaces development (https://www.sman3sltg.sch.id/2022/04/gandeng-pt-marimas-sma-negeri-3.html). These activities strengthened school-community ties while giving students a tangible sense of their contribution to reducing carbon footprints (Makmara, 2009).

4. Knowledge Gains and Behavioral Shifts

Post-test scores revealed a marked improvement in students' understanding of climate-related topics.

Table 2 compares pre- and post-test results

Test Item	Data	
	Pre Test	Post Test
Understanding the greenhouse effect	45	85
Knowledge of the carbon cycle	50	80
Awareness of air pollution causes	55	90
Ability to propose solutions	40	75

Students reported greater motivation to adopt sustainable practices, indicating the effectiveness of the teaching approach (Setyaputri et al., 2016).

Conclusion

Integrating climate change education into chemistry lessons has proven to be a powerful way to enhance environmental literacy and inspire actionable behaviors among students. By combining practical experiments, interdisciplinary methods, and local cultural elements, the program at SMA Negeri 3 Salatiga equips students with the tools to address environmental challenges effectively. This approach highlights the potential for education to be a catalyst for sustainability (Winkel & Hastuti, 2005).

Future initiatives could explore expanding these methods to other schools and leveraging digital tools like virtual labs for broader impact. For instance, platforms such as PhET Interactive Simulations can provide students with hands-on virtual experiments to deepen their understanding of complex scientific phenomena.

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