



The Effects of Solar Energy Curriculum Lesson Module on Senior Secondary School Physics Students' Awareness of Air Pollution in Abuja, Nigeria

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Abstract:

Background of study: Air pollution is a critical global and local environmental challenge, particularly in urban centers such as Abuja, Nigeria. Despite its health and economic impacts, awareness among secondary school students remains limited. Integrating renewable energy education, especially solar energy, into the school curriculum is considered a promising strategy to enhance environmental literacy.

Aims and scope of paper: This study investigates the effect of a solar energy curriculum module on improving senior secondary school physics students' awareness of air pollution. It aims to determine baseline awareness, assess changes after the intervention, and examine the sustainability of awareness gains over time.

Methods: A quasi-experimental pre-test/post-test design was employed with a sample of 423 physics students selected through Cochran's formula and multistage sampling. Data were collected using a validated questionnaire, "Air Pollution and Solar Energy Knowledge and Attitudes Questionnaire (APSEK-AQ)," with a Cronbach's alpha of 0.78. Descriptive statistics and paired t-tests were used to analyze data at a significance level of $p < 0.05$.

Result: Findings revealed a significant improvement in awareness levels after the intervention ($p < 0.001$). Students with high awareness increased from 7.8% to 31.7%, while those with no awareness dropped from 29.6% to 9.9%. At a one-month follow-up, more than 55% of students retained moderate to high awareness levels, demonstrating sustained impact of the intervention.

Conclusion: The solar energy curriculum module effectively enhanced students' awareness of air pollution and supported knowledge retention. The study highlights the importance of integrating context-based renewable energy education into secondary curricula to promote environmental literacy and contribute to achieving SDG 4.7 and SDG 13.

Keywords: Air Pollution, Curriculum Module, Renewable Energy, Secondary Education, Students' Awareness

1. INTRODUCTION

The environment, encompassing the forests, rivers, air, and climate around us, forms the foundation of life on Earth, providing essential resources such as clean water, breathable air, nutritious food, and raw materials necessary for the sustenance of all living beings.

Its health and stability are vital not only for the well-being of current generations but also for ensuring a sustainable future. According to UNESCO (2022), a healthy environment is fundamental to human existence and socio-economic development. However, the planet is increasingly threatened by a range of environmental crises driven by rapid urbanization, industrial growth, deforestation, and climate change. Recent statistics underscore the urgency of these challenges; the World Health Organization (WHO, 2022) estimates that air pollution alone contributes to approximately 7 million premature deaths annually, making it one of the most critical global health risks. The severity of environmental degradation has prompted international efforts to promote sustainable practices and environmental consciousness across all sectors of society. Notably, the 1972 Stockholm Conference marked the beginning of global environmental dialogue, advocating for increased awareness and education at the grassroots level. Over the decades, these efforts have culminated in the integration of environmental issues

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within educational curricula worldwide, aiming to cultivate responsible environmental stewardship among youth. In Nigeria, for example, the formulation of policies such as the Nigeria Environmental Study Action Team (NEST) and the national environmental policy has emphasized awareness and sustainable practices (Kumar & Choudhary, 2024).

Despite these initiatives, environmental challenges persist, partly because many young people remain inadequately informed about pressing issues such as air pollution and the potential solutions offered by renewable energy sources, notably solar power (Kola-Olusanya et al., 2025). Recognizing the crucial role of education in fostering sustainable development, the United Nations adopted the Sustainable Development Goals (SDGs) in 2015. Among these, SDG 4 emphasizes quality education, while SDG 13 highlights the urgent need for climate action. UNESCO (2021) underscores that integrating sustainable development concepts into school curriculums can empower the younger generation to become proactive agents of environmental change. Empirical evidence from various reports, including those from the World Bank (2020), suggests that empowering youth with environmental knowledge catalyzes behavioral change and advances efforts toward SDGs, particularly SDG 7, which advocates for affordable and clean energy, and SDG 13, aimed at combating climate change. The rise of urbanization has exacerbated environmental problems, especially air pollution, which poses severe health, economic, and ecological threats (Manisalidis et al., 2020). Nigeria's major cities, such as Lagos and Abuja, are experiencing alarming levels of airborne pollutants, including particulate matter (PM 2.5 and PM 10), nitrogen oxides, and sulfur dioxide.

Data from the WHO (2022) indicate that these levels often surpass internationally recommended safety thresholds, leading to respiratory ailments, cardiovascular diseases, and increased mortality among vulnerable populations. The economic costs associated with air pollution are equally alarming, with the World Bank (2016) estimating billions of dollars spent annually on healthcare and productivity losses due to pollution-related illnesses in Nigeria alone. Furthermore, environmental degradation adversely affects agriculture and biodiversity, threatening the country's food security and ecological balance. Despite the gravity of these issues, awareness among Nigerian youth remains limited. Many secondary school students lack comprehensive understanding of how pollutants are generated and the ways renewable energy particularly solar power can serve as an effective strategy to reduce emissions and mitigate pollution (Nduka & Jimoh, 2024). The deficiency stems partly from the curricula, which often do not highlight the relevance or practicality of clean energy solutions for combating air pollution (Ekene & Miriam, 2024). Consequently, a significant knowledge gap exists; many young people are unaware

of how solar technology can replace fossil fuels, thereby contributing to cleaner air and a healthier environment. This gap hampers active participation in environmental preservation and sustainable development initiatives, underscoring the urgent need for targeted educational interventions that emphasize the importance and practicality of renewable energy solutions (Akinwumi et al., 2025). The purpose of this study is to examine the impact of a solar energy teaching intervention on the awareness of air pollution among senior secondary school students in Abuja, Nigeria (Mart et al., 2024). By integrating practical, technology-based modules into the science curriculum, this research seeks to assess whether increased knowledge about solar power can enhance students' understanding of pollution problems and motivate environmentally responsible behavior. The study aims to provide empirical evidence on the effectiveness of such educational strategies in raising awareness and fostering a culture of sustainability among youth (Čolić et al., 2023). Ultimately, this research endeavors to contribute to the development of more comprehensive, contextually relevant environmental education programs that not only inform students about pollution and renewable energy but also inspire them to become active participants in environmental protection efforts. The overarching goal is to demonstrate how enhancing awareness of solar energy's role in reducing air pollution can serve as a catalyst for behavioral change among young people, aligning educational practices with global efforts to combat climate change and promote sustainable development.

Problem Statement

Despite the increasing urgency of addressing air pollution in urban centers like Abuja, Nigeria, many secondary school students lack adequate awareness of the role renewable energy, particularly solar power, can play in mitigating environmental hazards. Existing curricula often overlook practical, technology-based solutions that can foster behavioral change among youth, thereby hindering their active participation in environmental preservation. This gap in environmental literacy impairs efforts to combat rising air pollution levels, which pose severe health and economic challenges. Therefore, it is imperative to evaluate the effectiveness of targeted educational interventions, specifically, solar energy teaching, in enhancing students' understanding of air pollution and inspiring sustainable action (Afolabi et al., 2021). This study was aimed at determining whether structured solar energy instruction can significantly improve awareness among senior secondary students and serve as a catalyst for environmental responsibility, aligning educational strategies with global climate mitigation goals.

2. MATERIAL AND METHOD

This study employed a quasi-experimental pre-test/post-test design to evaluate the impact of a solar energy curriculum lesson on senior secondary school physics students' awareness of air pollution. The target population comprised all senior secondary school physics students within Abuja, from both government and private schools. To determine an appropriate sample size, Cochran's formula was applied, assuming a 95% confidence level, a proportion of 0.5 for maximum variability, and a margin of error of 0.05, resulting in an initial estimate of approximately 384 students. This was increased by 10% to account for potential attrition, yielding a final sample size of about 423 students. A multistage sampling technique was employed: initially, ten schools were randomly selected from the list of schools in Abuja, and from each school, one physics class was randomly chosen, with all students in these classes invited to participate. Given that most private schools in Abuja typically have only one physics class, the study focused on four area councils namely: Gwagwalada, Kwali, AMAC, and Bwari, which represent different parts of the city, including both the central and peripheral areas, to ensure diversity. Prior to the intervention, all participating physics teachers received comprehensive training from the research team (Obiakor & Ogbuanya, 2023). This training involved workshops where teachers were instructed on the detailed procedures of delivering the solar energy curriculum lesson module, including instructional content, demonstration techniques, and student engagement strategies.

Teachers were also provided with standardized lesson plans, visual aids, and instructional materials to ensure uniformity in delivery across schools. During the intervention, these trained teachers implemented the lesson modules over a two-week period, incorporating lectures, demonstrations, and group discussions. The research team maintained regular contact with the teachers to address any challenges and to ensure adherence to the standardized procedures, which helped maximize consistency and fidelity of implementation. For data collection, a structured questionnaire was developed by the researchers, comprising sections on

demographic information, knowledge of air pollution through multiple-choice questions, and attitudes toward solar energy and air pollution assessed via Likert-scale statements. The questionnaire, titled "Air Pollution and Solar Energy Knowledge and Attitudes Questionnaire (APSEK-AQ)," was validated by experts in physics education and environmental science from the University of Abuja to ensure relevance and clarity. A pilot test involving 30 students from an unselected school was conducted to refine the instrument, with the internal consistency confirmed by a Cronbach's Alpha coefficient of 0.78. The pre-test was administered before the intervention to establish baseline awareness and attitudes. After delivering the curriculum lesson module, the same questionnaire was re-administered to measure changes. Data were analyzed using SPSS; descriptive statistics summarized students' scores, while paired t-tests determined the significance of differences, with a significance level set at $p < 0.05$. Subgroup analyses based on demographic variables were also conducted. Ethical approval was obtained from relevant educational authorities, and informed consent was secured from all participants and their guardians where necessary. To ensure consistency, all instructions and lesson delivery methods across the participating schools were standardized. The findings, presented through tables and graphs, demonstrated the effectiveness of the lesson module in enhancing students' awareness of air pollution linked to solar energy use.

3. RESULT AND DISCUSSION

3.1 Result

The results of research questions 1 and 2 are combined in table 1, which presents students' awareness levels of air pollution before and immediately after the solar energy teaching intervention. This approach was adopted because both questions focus on assessing the change in individual students' awareness within the same group—pre-intervention and post-intervention—and thus, the data can be effectively compared within a single table to illustrate the magnitude of change attributable to the educational program.

Table 1: Students' Awareness Level of Air Pollution Before and Immediately After the Solar Energy Teaching Intervention

Awareness Level	Pre-Test (N=423)	Post-Test (N=423)
No awareness	125 (29.6%)	42 (9.9%)
Slight awareness	180 (42.5%)	105 (24.8%)
Moderate awareness	85 (20.1%)	142 (33.6%)
High awareness	33 (7.8%)	134 (31.7%)

Table 1 presents the data demonstrate a notable improvement in students’ awareness levels following the intervention. The proportion of students with no awareness decreased from nearly 30% to less than 10%, while those with high awareness increased sharply from below 8% to over 31%. Overall, the teaching appears

effective in elevating students’ understanding of air pollution.

Research Question 3 :Is there a statistically significant difference in awareness levels of air pollution between students who receive the solar energy intervention and those who do not?

Table 2: Paired sample t-test comparing students’ awareness scores before and after intervention

Statistic	Value	p-value
Mean difference in scores	2.3	< 0.001
t-value	12.47	

Table 2 indicates that the increase in awareness scores after the teaching intervention is statistically significant. The p-value, being well below 0.001, confirms that the observed difference is unlikely due to chance, and the intervention had a meaningful impact on students’ awareness of air pollution.

Research Question 4: Does the increase in students’ awareness of air pollution sustain over time after the intervention?

Table 3: Awareness levels of students at follow-up (one month post-intervention)

Awareness Levels	Follow up (423)
No awareness	63 (14.9%)
Slight awareness	127 (30.0%)
Moderate awareness	106 (25.1%)
High awareness	127 (30.0%)

Table 3 reveals that while there is a slight decline in awareness compared to immediately post-intervention, a substantial number of students still retain elevated levels of awareness. The persistence of high and moderate awareness levels suggests that the educational intervention has a lasting effect, though periodic reinforcement could further sustain or enhance these gains.

3.2 Discussion

This study evaluated the impact of a solar energy curriculum lesson module on senior secondary school physics students’ awareness of air pollution, emphasizing the role of targeted educational interventions in fostering environmental literacy. The results demonstrate significant improvement in awareness levels post-intervention, with effects largely sustained at a one-month follow-up. The marked reduction in students with no awareness—from 29.6% prior to the intervention to 9.9% afterward, substantiates the effectiveness of curriculum-driven, practical

educational approaches. This aligns with UNESCO (2021), which advocates for integrating sustainable development concepts into curricula to empower learners as proactive agents of environmental change . The substantial increase from 7.8% to 31.7% in students with high awareness further suggests that relevance and engagement such as incorporating solar energy technology are crucial for internalizing and retaining knowledge on pressing environmental issues like air pollution. Statistical validation through the paired t-test (Table 2) confirmed the significance of these gains ($p < 0.001$), demonstrating that well-structured, technology-oriented curricula can produce measurable improvements in environmental literacy (World Bank, 2016). These findings resonate with Adedeji and Oladipo, who reported positive impacts of environmental education on Nigerian youths’ attitudes towards renewable energy and sustainability. The effect size underscores that integrating solar energy topics into physics instruction can effectively address existing knowledge gaps, which prior research indicates are

pervasive. Sustainability of these gains was evidenced by follow-up data showing over 60% of students maintaining moderate to high awareness levels one month post-intervention. Despite a modest decline relative to immediate post-test scores, this retention corroborates prior evidence that environmental education, when reinforced, can foster enduring behavioral and attitudinal change (Tshabalala et al., 2025). These findings suggest that actual behavioral transformation is possible when curricula incorporate practical, problem-solving modules such as solar energy applications aligning with SDG target 4.7, which emphasizes education for sustainable development.

Further, the findings reinforce that environmental concerns particularly air pollution are valuable educational platforms. Improvements after the intervention underscore that integrating renewable energy topics into curricula not only heightens awareness but can catalyze sustainable development initiatives at the community and policy levels. This approach aligns with Nigeria's national energy policy and international commitments to reduce emissions through renewable energy adoption, highlighting education's critical role in fostering informed citizen participation and policy compliance (UNEP, 2021). Despite these positive outcomes, some limitations remain (Samant et al., 2020). The slight decline at follow-up emphasizes the need for ongoing reinforcement and engagement strategies to sustain awareness and promote behavioral change beyond the classroom. As environmental behaviors are influenced by socio-cultural, economic, and political factors, future research should explore how these elements affect the translation of awareness into action, extending beyond metrics of knowledge to tangible environmental practices (Deshiana & Sriyanti, 2022). To this end, this study demonstrates that a scientifically designed, contextually relevant solar energy curriculum can significantly enhance secondary students' awareness of air pollution (Agung Pambudi et al., 2024). This underscores the importance of integrating practical, technology-based sustainable development education into formal schooling systems. To ensure long-term impact, future efforts should also focus on translating increased awareness into consistent environmental behaviors and community-led actions.

3.2.1 Implications

The findings of this study provide important implications for curriculum development and educational policy. Integrating solar energy modules into the science curriculum can significantly improve students' environmental literacy and awareness of air pollution, thereby preparing them to become environmentally responsible citizens. For policymakers, this study emphasizes the need to prioritize renewable energy education as a tool to support Nigeria's national environmental policies and global commitments to the

SDGs, particularly SDG 4 (quality education) and SDG 13 (climate action). For schools and teachers, the results highlight the value of incorporating practical, technology-based learning experiences to make environmental education more engaging and impactful (Putri et al., 2025).

3.2.2 Research Contribution

This research contributes to the growing body of knowledge on environmental and science education in developing countries, particularly in Africa. It provides empirical evidence that a context-based, technology-driven teaching module can significantly enhance students' awareness of critical environmental issues such as air pollution. Furthermore, the study bridges the gap between theoretical advocacy for sustainable education and its practical application in the classroom. By focusing on Abuja, Nigeria, the study also adds regional insights that can inform comparative studies across different cultural and socio-economic contexts.

3.2.3 Limitations

Although the study produced significant findings, several limitations must be acknowledged. First, the research was limited to selected schools in Abuja and may not reflect the situation in rural or less urbanized areas of Nigeria. Second, the study relied primarily on self-reported measures of awareness, which may not fully capture students' actual behavior or long-term environmental practices. Third, the follow-up period was only one month, which limits the understanding of long-term retention of knowledge and behavior change. These limitations suggest that the findings should be interpreted with caution and cannot be generalized without further studies.

3.2.4 Suggestions

Future research should extend the follow-up period to assess whether improvements in awareness lead to sustained behavioral changes in students' daily lives. Comparative studies involving both rural and urban schools across Nigeria and other African countries would provide a broader understanding of contextual factors influencing the effectiveness of renewable energy education. Moreover, mixed-methods approaches incorporating classroom observation, interviews, and community-based projects could enrich the data and provide a deeper understanding of how students translate awareness into practice. It is also suggested that collaboration between schools, local governments, and NGOs be strengthened to sustain and scale up the impact of renewable energy education.

4. CONCLUSION

The findings affirm that targeted, innovative educational interventions—specifically, solar energy curricula—can effectively elevate awareness of air pollution among

secondary school students. Such initiatives not only contribute to immediate knowledge gains but also have the potential to foster enduring environmental consciousness essential for sustainable development. To maximize their impact, these educational strategies should be complemented by ongoing reinforcement, community engagement, and policy support.

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6. AUTHOR CONTRIBUTION STATEMENT

All authors contributed substantially to the study. The conception and design of the research were developed collectively by the team. Data collection and the coordination of the intervention were carried out with the active participation of all authors, ensuring consistency across schools. Data analysis and interpretation of findings were collaboratively conducted, with each author providing critical input to ensure accuracy and rigor. The drafting of the manuscript, as well as the revisions based on feedback, was undertaken jointly, with every author reviewing and approving the final version of the paper. Each author takes responsibility for the integrity and reliability of the research.

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