World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Knowledge, Understanding, and Awareness of Climate Change and Sustainability through Science Education: A Student Engagement in Project-Based Learning Interventions

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World Journal of Advanced Research and Reviews, 2025, 28(01), 2226-2240

Publication history: Received on 12 September 2025; revised on 28 October 2025; accepted on 31 October 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.28.1.3593

Abstract

This study examines how Project-Based Learning (PBL) can enhance students' understanding and awareness of climate change and sustainability within the context of science education at General Emilio Aguinaldo National High School in Imus City. Recognizing the urgent need to integrate environmental education into the curriculum, the research employed a mixed-methods approach combining quantitative surveys and qualitative focus group discussions. The PBL intervention was implemented over a three-month period, engaging Grade 10 learners in hands-on, real-world projects focused on climate and sustainability issues. Findings revealed that learners demonstrated a moderate to high level of knowledge and awareness of climate change, particularly regarding its causes, impacts, and global mitigation efforts. PBL activities significantly improved students' conceptual understanding, engagement, and confidence, enabling them to connect classroom learning with real-world applications. Qualitative data further highlighted that students developed a holistic understanding of environmental issues, extending beyond reducing carbon footprints to include biodiversity conservation and personal accountability. However, challenges such as academic workload and the need for differentiated tasks emerged. This study concludes that PBL is a practical pedagogical approach for fostering environmental literacy, critical thinking, and responsible citizenship among learners. It recommends further integrating PBL-based climate education across disciplines, communities, partnerships, and utilizing interactive learning materials to deepen sustainability awareness and promote active participation in climate action.

Keywords: Project-Based Learning (PBL); Climate Education; Sustainability; Sustainability Awareness; Science Education; Environmental Literacy

1. Introduction

Climate change is a broad issue that the education sector has an important role to play. Climate change is a pressing issue that requires immediate attention and action. The education sector continuously responds to these challenges by shaping the future generation's understanding of climate change and sustainability. Science education is uniquely positioned to foster a deep understanding of climate science, environmental impact, and sustainable practices among students. Integrating climate change and sustainability into the curriculum is crucial for equipping students with the knowledge, skills, and attitudes necessary to navigate and address these complex issues. General Emilio Aguinaldo National High School - Imus City, like other educational institutions, supports and prepares learners to navigate the complexities of a changing world. The effects of climate change and the need for sustainability require action. However, integrating climate change into the science curriculum requires innovative approaches that go beyond traditional teaching methods.

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However, the school's location in a region susceptible to the impacts of climate change, such as extreme weather events and environmental degradation, makes this research study particularly relevant. Students at General Emilio Aguinaldo National High School must be prepared to understand the scientific concepts of climate change to engage in sustainability practices that can actively mitigate its effects. Furthermore, the importance of climate change in education and its integration into curricula needs a more profound understanding. Schools must prioritize these topics amidst a crowded curriculum, honing learners to have a broader understanding of climate change despite the growing technology and human activities that contribute to it. Aligning to the RA No. 9729 or the Climate Change Act of 2009 and the Enhanced Basic Education Curriculum Act of 2013, or the strengthened curriculum integration of key climate change concepts across the grade level, broadening the knowledge of learners to the effects of climate change and how learners can be a part of a solution to combat the said environmental issues.

Innovative educational strategies that can effectively engage students and enhance their understanding of climate change and sustainability are needed to address the gaps in climate change education. Learners' and teachers' classroom engagement will be an eye-opener to their environmental awareness, as learning the main concepts in the classroom will be a part of their learning.

Meanwhile, Project-Based Learning (PBL) presents a unique opportunity to enhance the science curriculum by making climate change and sustainability education more interactive and relevant to students' lives (Risamasu, P. V. M., et al., 2024) [15]. Embracing project-based learning (PBL) as a learning delivery approach promotes student-teacher engagement while fostering academic growth and well-being (Rubino, 2024). [16] Student involvement in hands-on, real-world projects encourages active learning, critical thinking, and problem-solving skills. Project-based learning makes the learning environment more engaging and relevant, allowing for a deeper understanding of the subject matter (Genc, 2014). [6] Furthermore, PBL can be a powerful tool for increasing student engagement, which is crucial for effective learning and retention.

Moreover, student engagement is a crucial factor in the success of any educational initiative. Project-based learning (PBL) has been shown to significantly enhance student motivation and engagement, leading to improved learning outcomes. Using a project-based learning (PBL) intervention focused on climate change and sustainability, General Emilio Aguinaldo National High School in Imus City enhances students' understanding, inspiring them to become more proactive agents of change in their communities.

This research examines how project-based learning (PBL) can be utilized to enhance climate change and sustainability education in conjunction with science education at General Emilio Aguinaldo National High School in Imus City. By prioritizing the topics within the science curriculum and engaging students through PBL, the school has the potential to produce a generation of learners who are well-informed, environmentally conscious, and equipped to contribute to a sustainable future.

2. Review of Related Literature

Science education holds significant potential to be a powerful tool in adapting to climate change and addressing the climate emergency Dunlop & Rushton, 2021) [2]. Learners and educators collaborate to combat climate change, honing learners into resilient individuals who possess relevant content knowledge on climate change, social issues, and the institutional environment. This knowledge is implemented in the education system to promote a resilient and climate-resilient sustainable environment in schools and communities (Anderson, 2013). [1] Education for Sustainable Development (ESD) prioritizes high-quality learning outcomes by focusing on both content and learning processes, with a strong emphasis on contributing to environmental sustainability and addressing climate change. Perwitasari, S., Hariyono, E., & Susantini, E. (2023) [12]. Education for Sustainable Development (ESD) continually shapes the mindset and lifestyles of learners, both now and in the future, by integrating project-based learning (PBL) approaches. This approach is considered effective in enhancing students' understanding of climate change and sustainability Khoiri, N., Hayat, M., & Siskawati, D., 2023) [8].

Despite curriculum overload and limited resources, schools have successfully integrated climate change into their curricula and employed innovative teaching strategies, embracing community engagement and technology integration to promote environmental literacy Fan, Chen, Xiang, & Fan, 2024) [5]. The Science Education in K to 12 program's conceptual framework aims to produce learners who are inclined toward scientific, technological, and environmental literacy (DepEd, 2016) [19]. Private and public schools work together to strengthen environmental awareness, preservation, and protection, integrating science subjects and other learning areas to promote ecological conservation, utilizing the science instructional materials to promote a broader understanding of environmental education, as stated on DO: no. 52, s 2011. The education sector continually designs curricula and learning delivery approaches that

integrate climate change and sustainability. Climate change was also strengthened by implementing DRRM to develop the resiliency of teachers and students, providing knowledge on the adaptability to climate change across the learners in Junior High School level, Fale, M. T. L. (2022) [5] In partnership with DENR and other school related organization like YES-O, climate change has been part of their project in every school, to deepen the knowledge of learners about the possible effects of pollution and in surroundings associated with climate change effects on the natural phenomena—additionally, students' engagement and experiences in science classrooms and other learning environments. Integrating climate change into the high school curriculum provides deeper insights for learners to achieve the sustainable development of the environment, Evey, C. K. (2021, [4]

Moreover, based on a review of the related literature, teaching about climate change has a positive effect on students, enhancing their creativity and environmental responsibility through project-based learning. This approach also strengthens physics education by linking it to real-world phenomena Lestari, N., Susanti, F., Deta, U., Hariyono, E., & Madlazim, M., 2024) [9]. Project-based Based Learning is more effective in enhancing critical thinking skills, and taking action on climate change can improve learners' engagement with science by highlighting its relevance to real-world issues and linking education to project-based learning and community-driven efforts, R. Wulan, A.Utiya & N.Harun (2024), [14]

To address climate change and sustainability education, it is essential to implement a real-world curriculum and support cross-curricular practices through teacher training Okada & Gray, 2022), [11].

Synthesis

Project-based learning (PBL) has been integrated into science education to significantly enhance students' environmental attitudes and awareness. In science education, a study involving university students showed that PBL activities are notable to their positive perceptions of sustainability, including increased efficacy and responsive to environmental issues, Perrault, E. K., et.al., (2017), [10]; on the other hand, similar research was conducted to secondary schools' students, shown that PBL methodologies are effective, improved the student's environmental awareness. Students who participate in projects related to the local environment have significantly and statistically increased their ecological awareness and consciousness, and fostered positive attitudes towards the environment, Lopez J. A et al. (2024), [13]

Furthermore, applying PBL in environmental education has been associated with increased creativity, enhanced research skills, and permanent learning outcomes. Students believed that this practice helped them to define the current issues and or environmental problems more clearly and to take on more active tasks in the solution process, Genc, M. (2014), [6]

2.1. Research Questions:

- What is the student's level of understanding and awareness regarding climate change and sustainability issues at General Emilio Aguinaldo National High School-Imus City?
- What are the practices for integrating project-based learning into the science curriculum to prioritize climate change and sustainability education, and how can these practices be recommended for wide-range implementation?
- How can project-based learning interventions be effectively crafted and integrated into science education to engage students with climate change and sustainability topics?
- What effect does the project-based learning intervention have on students' understanding and awareness of climate change and sustainability compared to their pre-intervention knowledge and awareness?

2.2. Scope and Limitation of the Study

This study aims to enhance students' understanding and awareness of climate change and sustainability by implementing a project-based learning (PBL) intervention within the science curriculum at General Emilio Aguinaldo National High School in Imus City. This will involve grade 10 learners, with approximately 30 per section being selected through stratified random sampling to ensure representation across the learners. The PBL intervention is designed to integrate climate change and sustainability topics into the science curriculum and will be implemented over a period of three months or one quarter. Pre-and post-intervention assessments will be conducted to evaluate the impact of the intervention. Data collection will be performed using both quantitative and qualitative methods. Quantitative data will be obtained from surveys administered before and after the intervention, while qualitative data will be gathered through focus group discussions and interviews.

However, the study's findings are specific to General Emilio Aguinaldo National High School in Imus City. They may not be generalizable to other schools or regions with different environments or educational contexts. Additionally, the study's sample size, comprising a limited number of students — 20-30 per section — may restrict the broader applicability of the results. The intervention will be fixed over a period of time, which may limit the ability to observe the student engagement and understanding.

2.3. Significance of the Study

This study holds promise for its potential impact on education and community engagement. Educationally, it aims to enhance students' understanding and awareness of climate change and sustainability, thereby enabling them to address global challenges more effectively. Using PBL in the science curriculum, this research promoted innovative teaching methods that make climate change and sustainability education more engaging and relevant to students' lives.

Practically, the outcome of this research could also inform educators about the inclusion of climate change and sustainability topics in school curricula, thereby contributing to a broader understanding in the field of education.

Furthermore, incorporating community and environmental perspectives can increase students' engagement with climate change and sustainability topics, fostering greater ecological awareness and proactive behavior in school and the community. The study addresses local environmental concerns by focusing on a school situated in a region affected by climate change. Additionally, it will contribute to the development of educational strategies tailored to the specific needs and challenges of the community.

3. Research Design and Methodology

This research will employ a mixed-methods approach, combining quantitative and qualitative research methods, to provide a comprehensive understanding of the impact of project-based learning (PBL) interventions on students' engagement with climate change and sustainability topics. Using a researcher-made questionnaire, learners will be assessed for their understanding and awareness of climate change sustainability before the PBL intervention. Develop and implement the PBL intervention, involving the iterative cycles of planning, action, observation, and reflection. Qualitative analysis methods will be used to gather insights into students' experiences and the effectiveness of the PBL intervention, using focus group discussions.

3.1. Sampling Method

Stratified random sampling will be utilized to ensure representation across the science education. Approximately 20-30 students will be selected to provide sufficient data for both quantitative and qualitative analyses.

3.2. Data Collection

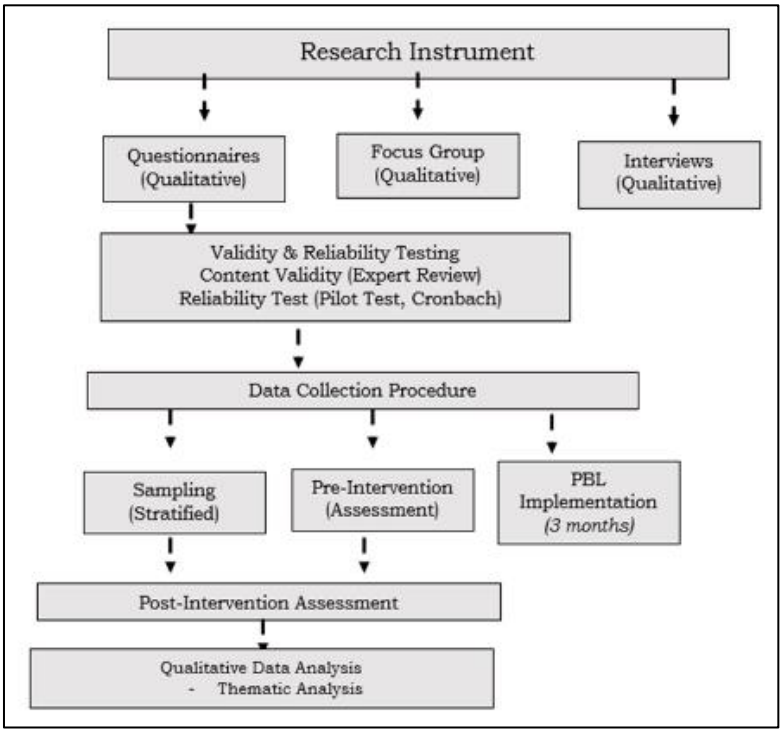

Figure 1 Data Collection Framework

The figure above illustrates the data collection framework, which outlines the research instruments used, including questionnaires, focus group discussions, and interviews. It also details the validity and reliability testing procedures, sampling techniques, pre-intervention and post-intervention assessments, and the implementation of the three-month project-based learning (PBL) program, leading to a thematic qualitative analysis.

3.3. Data Analysis Plan

3.3.1. Quantitative Analysis

Descriptive statistics will be utilized to assess the understanding and awareness of climate change and sustainability. Means, standard deviations, and frequencies will summarize the data and describe the overall level of experience and engagement. Paired sample T-test will be used for pre-test and post-test, and the SPSS software will be used for statistical data analysis, and will be interpreted by the statistician, Stephen T. Fife and Jacob D. Gossner (2024) [7]

Table 1 Likert scale, weighted values, and verbal interpretation used for analyzing the respondents' perception ratings.

Weight /Scale	Likert Scale Interval	Verbal Interpretation
5	4.21-5.00	Strongly Agree
4	3.41-4.20	Agree
3	2.61- 3.40	Neutral/ Uncertain
2	1.81-2.60	Disagree
1	1.00 – 1.80	Strongly Disagree

3.3.2. Qualitative Analysis

Thematic Analysis is conducted on the interview and focus group discussion transcripts to identify recurring themes and patterns related to students' experiences with the PBL intervention. Coding scheme to categorize qualitative data into meaningful themes, such as student engagement, perceived effectiveness, and challenges faced, Miles, Huberman, and Saldaña (2018)

3.4. Ethical Considerations

This research is conducted responsibly, respectfully, and in compliance with the Department of Education's outline of the Basic Education Research Agenda and Research Guidelines, as well as relevant management and legal standards. This research fully adheres to and establishes the ethical principles in considering the participation of minors in academic settings. Informed consent will be obtained from the parents/guardians, while assent will be sought from the student participants to ensure voluntary participation. All collected data are treated with strict confidentiality and anonymity, ensuring that individual identities are fully protected throughout the study process. The principle of non-maleficence will be upheld by minimizing the harm or discomfort to the participants. In contrast, the principle of beneficence will guide the study to promote positive outcomes and contribute to the improvement of educational practices.

Before data collection, the research will be conducted with complete transparency and integrity, maintaining honesty and accuracy at every stage.

4. Results and Discussion

This part of the research explores the study's results, discussing the underlying issues related to the knowledge, awareness, and understanding of climate change among grade 10 learners.

Table 2 Knowledge of Climate Change and Sustainability

Indicators	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	MEAN	STD	Verbal Interpretation
	-1	-2	-3	-4	-5				
I am aware of the causes of climate change (e.g., greenhouse gas emissions).	3	3	12	37	28	83	4.01	0.98	Agree
I am aware of the primary causes of climate change.	1	3	19	42	18	83	3.88	0.83	Agree
I understand the role of human activities in contributing to climate change.	1	2	25	41	14	83	3.78	0.79	Agree
I can identify the key scientific concepts related to sustainability.	3	15	36	22	7	83	3.18	0.95	Neutral
I know the differences between renewable and non-renewable	3	8	27	27	18	83	3.59	1.04	Neutral

energy sources.									
I understand how climate change impacts ecosystems and biodiversity.	4	0	25	26	28	83	3.89	1.03	Agree
I am familiar with sustainable practices that can help mitigate climate change.	5	6	33	27	12	83	3.42	1.02	Neutral

Data Interpretation:

The table above shows the learners' knowledge of climate change and sustainability. It discusses the breadth of their knowledge and understanding of climate change, with an average of 3.68, which exemplifies the respondents' responses at a moderate to agreeable level of knowledge regarding climate change and sustainability. Meanwhile, the standard deviation (SD) is 0.95, indicating low variation in responses, meaning the responses across respondents are relatively consistent.

In summary, the respondents generally show a moderate understanding of climate change and sustainability topics. Indicators 1 and 2, which are the primary causes of climate change, have the lowest mean scores, indicating a need for targeted reinforcement or further clarification in these areas. On the other hand, the impact of climate change on the ecosystem has led to a deeper understanding of scientific concepts. The low standard deviation indicates that most respondents share a similar level of awareness, which is positive in terms of group consistency.

Table 3 Understanding of Climate Change and Sustainability

Indicators	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**TOTAL**	**MEAN**	**STD**	**Verbal Interpretation**
	1	2	3	4	5				
I understand the concept of sustainability and its importance.	1	7	34	30	11	83	3.52	0.87	Agree
I can identify ways to reduce my carbon footprint.	2	12	38	25	6	83	3.25	0.88	Neutral
I understand the importance of reducing carbon footprints for sustainability.	3	8	38	25	9	83	3.35	0.92	Neutral
I understand how sustainable	1	4	31	34	13	83	3.65	0.84	Agree

practices can impact future generations.									
I can analyze the relationship between climate change and biodiversity loss.	2	12	24	34	11	83	3.48	0.97	Neutral
I am aware of the role of international agreements in promoting sustainability.	3	13	31	24	12	83	3.35	1.02	Neutral
I understand the connection between climate change and social justice issues.	5	14	28	24	12	83	3.29	1.09	Neutral

Data Interpretation:

Table 3 presents the interpretation of data based on the survey results across respondents, with a mean of 2.65, indicating that the indicator is 4, which suggests a strong awareness of the benefits of sustainability and its impact on future generations. The standard deviation (STD) ranges from 0.84 to 1.09, indicating variation in responses, particularly in indicators 6 and 7, which suggests a mixed level of awareness.

Furthermore, the results of the gathered data indicate that respondents possess a moderate to high level of understanding of climate change and sustainability concepts, with particular strengths in grasping the importance and long-term implications of sustainability. However, more focused efforts are needed to strengthen the knowledge on practical applications, global agreements, and social justice aspects.

Table 4 Awareness and Sustainability

Indicators	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**TOTAL**	**MEAN**	**Verbal Interpretation**	**STD**
	1	2	3	4	5				
I am aware of the current global efforts to combat climate change.	3	3	23	40	14	83	3.71	Agree	0.91
I pay attention to news and reports about climate change and sustainability.	3	5	26	35	14	83	3.63	Agree	0.95
I believe my actions can make a difference in	4	8	21	35	15	83	3.59	Agree	1.04

addressing climate change.									
I am conscious of my daily habits that contribute to sustainability.	3	6	33	28	13	83	3.51	Agree	0.96
I am aware of the long-term consequences of ignoring climate change.	4	7	20	31	21	83	3.70	Agree	1.08
I am informed about the local and global initiatives aimed at promoting sustainability.	2	5	29	36	11	83	3.59	Agree	0.88

Data Interpretation:

Table 4 shows that respondents consistently agree with seven indicators, with scores ranging from 3.51 to 3.71. The highest mean is 3.71 for indicator 1, suggesting a strong awareness of global efforts. The lowest mean is 3.51 for indicator 4, which focuses on daily sustainable habits; this is the target area for improvement. The standard deviation, which ranges from 0.88 to 1.08, shows moderate variability in individual awareness and attitudes. The data shows a solid understanding and positive attitudes toward climate change and sustainability. In general, they are informed and believe in their individual impact, and they express concern about long-term consequences. It suggests the widespread awareness of some variables, specifically in personal behavior and community participation. The future effort should focus on strengthening sustainable practices in daily routine and reinforcing the connection between individual action and global impact.

Table 5 Engagement in Project-Based Learning

Indicators	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**TOTAL**	**MEAN**	**STD**	**Verbal Interpretation**
	1	2	3	4	5				
The project-based learning activities enhanced my understanding of climate change.	2	2	23	42	14	83	3.77	0.84	Agree
I felt more engaged in learning about sustainability through project-based activities.	1	3	27	37	15	83	3.75	0.83	Agree
The projects helped me connect theoretical	1	5	30	34	13	83	3.64	0.86	

knowledge with real-world climate issues.									Agree
I feel more confident in discussing climate change and sustainability after participating in these projects.	3	6	27	35	12	83	3.57	0.95	Agree
I believe that project-based learning is an effective way to teach climate change and sustainability.	1	2	15	46	19	83	3.96	0.78	Agree

Data Interpretation:

Table 5 shows that 83 respondents perceive PBL as effective in improving their understanding, engagement, and confidence in learning about climate change and sustainability. All indicators receive a mean between 3.57 and 3.96, which has a verbal interpretation of "Agree, "which shows the positive perceptions. The highest mean is 3.96 for indicator 5, indicating that learners widely believe in the effectiveness of project-based learning. In contrast, the lowest mean is 3.57 for indicator 4, suggesting that confidence has improved; however, some learners may still require support in expressing ideas on sustainability. On the other hand, the standard deviation (STD) ranges from 0.87 to 0.95, indicating moderate variability, with most learners generally agreeing, although some report differing experiences. Learners perceive project-based learning as an effective and engaging approach to understanding climate change and sustainability.

6.1 Question: Has your understanding of climate change and sustainability changed as a result of your participation in project-based learning?"

Table 6.1 Project-Based Learning Application

Theme	Category	Content	Response	Description
Awareness of Carbon Emissions	Carbon Footprint Awareness	Realizations that climate change goes beyond reducing carbon footprint	R1 "My understanding of climate change was not to reduce the carbon footprint that we use."	Learners reflect that understanding climate change is not just about limiting emissions, but also involves broader awareness.
Personal Accountability	Real-life application	Applying acquired knowledge to individual behavior	"I understand, then, by applying it to my daily life."	Learners connected the knowledge gained through personal decisions and daily habits
Environmental Concern	Awareness of Environmental Consequences	Impact of Climate Change on ecosystems, especially species that need cold climates	"I understand that climate change is hazardous to our environment, especially to some animals that need	Learners express concerns for wildlife and the destabilizing effect of climate change on the environment.

			cold temperatures and a stable living environment."	
Holistic Understanding	Conceptual Integration	Grasp of the relationship between sustainability and climate change	"This climate change helped me to understand how climate change and sustainability affect life."	Learners demonstrate a synthesized understanding of the interlinkage between climate change and sustainability.

Data Interpretation

Table 6.1 reveals the students' analysis based on their understanding of climate change and sustainability as influenced by project-based learning (PBL). The themes that were reflected significantly were those related to carbon emissions. The students expressed that their understanding had broadened beyond the basic notion of reducing a carbon footprint, indicating that PBL encourages broader thinking about environmental issues. Taking personal responsibility demonstrates a comprehensive understanding of how climate change impacts daily life, and PBL is not just about learning; it also informs and inspires students to act responsibly, fostering climate-conscious behavior among young people. Meanwhile, the learners also demonstrated an awareness of environmental concerns, focusing on the dangers to animal species, particularly in colder environments. Students' reflections indicate that PBL can be effective in cultivating advocacy and environmental stewardship among students.

Finally, learners have a holistic understanding, as one student noted how climate change and sustainability affect life as a whole. This focuses on the development of the thinking system, where learners begin to perceive the interconnections among environmental, social, and economic issues. A study projects that the results of Project-Based Learning (PBL) serve as a powerful prelogical tool for nurturing awareness, responsibility, empathy, and a comprehensive understanding of climate change-related challenges.

Question 6. 2: "What are the most impactful aspects of the project-based learning activities you participated in?"

Table 6.2 Project-based Learning Application

Theme	**Category**	**Content**	**Response**	**Description**
Active participation and engagement	Empowerment through engagement	Learners left motivated to contribute to positive environmental change	R1: "Engagement in Project-Based Learning because it engages people to participate in change and take care of our earth."	Students recognized the value of the PBL in inspiring collective responsibility for environmental action.
Academic Pressure	Stress workload	The student left, overwhelmed by the workload and activity demands	R2: "Too much pressure in doing activities."	Some learners may experience pressure from the volume of tasks involved in PBL.
Lack of impact	Lack of Relevance	Students often struggle to make PBL meaningful and impactful.	R3: "There is nothing impactful for me."	Not all learners were able to connect with PBL in the same way, indicating room for more inclusive design.
Cognitive and Conceptual Growth	Deeper understanding	Learner enhanced understanding of	R4: "I feel engaged and have enhanced my understanding of	PBL helped expand learners' knowledge of real-world issues,

		climate change and population dynamics	this PBL learning because it helped me to understand how climate change affects the population over time."	primarily environmental and societal topics.
Awareness of visible issues	Relevance to everyday life	Focused on a tangible, observable, and environmental problem like social waste	R5: The most impactful aspect for me is social waste because we can see it everywhere."	Students connect with PBL topics through visible, familiar issues that surround them.

Data Interpretation:

Table 6.2 presents key insights into experiences with project-based learning, with the theme of empowerment through engagement emerging as a strong one. Students shared PBL, actively participated, and became more conscious of environmental issues, particularly in caring for the earth. This engagement made their learning experiences more meaningful and action-oriented, which demonstrates that PBL can motivate learners to become agents of change when they see the real-world relevance of their projects.

However, stress and workload were identified as the primary concerns of respondents. Expressing feelings of being overwhelmed due to the pressure and demands of the activities. This suggests that PBL can foster deep learning, but it also necessitates careful planning, pacing, and teacher support to prevent burnout and learner disengagement. On the other hand, another important theme was the perceived lack of relevance; one respondent found nothing impactful in the activities, suggesting a disconnect between the project, content, and personal interest. This indicates that a differentiated task is necessary to accommodate the diverse learning styles and promote inclusivity and engagement among learners.

Furthermore, one of the key themes is a deeper understanding of complex issues, such as climate change and its connection to population growth. This suggests that PBL can cultivate critical thinking skills and interdisciplinary learning, particularly when lessons are grounded in real-world challenges and problems. Most importantly, the learners emphasized the relevance to everyday life. One student stated that social waste was an impactful topic because it is visible and relatable to the environment.

5. Conclusion

This chapter will explore the study's results, which encompass knowledge of climate change and sustainability, understanding of climate change and sustainability, awareness of sustainability, and engagement in project-based learning. The data has been interpreted quantitatively and qualitatively. The study reveals that learners generally have a moderate to high level of knowledge awareness regarding climate change and sustainability, with a mean of 3.68 in the first part. This demonstrates that learners have a sound understanding of climate change, which causes ecological impacts; however, some areas, such as the distinction between renewable and nonrenewable energy and the scientific concept of sustainability, require further discussion. In terms of understanding, learners demonstrate agreement in grasping the importance of sustainability and its long-term effects, especially for future generations; however, the response suggests a need for strengthened instruction on practical applications, international agreements, and social justice in the context of climate change**.** Furthermore, the dimension of awareness reveals that learners are highly informed about global efforts and the long-term consequences of climate inaction. Still, there is room for improvement in promoting consistent, daily, sustainable habits.

The most notable in this study is the engagement in project-based learning PBL, which proves effective, with high agreement levels on these activities boosting understanding, real-world connection, and learner confidence. The highest mean is 3.96 across all indicators, which affirms that learners believe in the value of PBL as an instructional approach for climate change. Using the PBL approach, learners broaden their understanding of climate change mitigation through simple yet effective methods, such as creating a media campaign, producing brochures, and conducting interviews with community leaders about their plans and practices for climate sustainability. They are immersed in various environmental activities that make them learn, innovate, and explore. Quantitatively, the data support the integration of contextualized, inquiry-based, and participatory strategies, like project-based learning, to

deepen students' understanding and commitment to sustainability. Targeted interventions in areas of lower comprehension and daily application can further enhance climate literacy and responsible action among learners.

Lastly, qualitatively, the themed data has a positive influence of Project-Based Learning (PBL) in fostering environmental awareness, critical thinking, and student engagement. Learners demonstrated a broadened understanding of climate change, moving beyond the idea of simply decreasing the carbon footprint to embrace biodiversity, responsibility, and an integrated perspective on sustainability. This shows the holistic comprehension that PBL effectively nurtures not only in knowledge acquisition but also in values, information, and behavioral change. Furthermore, students recognized the relevance of PBL to real-life issues, such as social waste, which enhanced the meaning of their learning experiences. The challenges, such as academic pressure and a perceived lack of relevance for some learners, should prompt careful implementation. Teachers must consider differentiated instruction, proper pacing, and adequate support to make PBL more inclusive and manageable (Gara, 2023). Project-based learning is a powerful educational tool that can develop informed, responsible, and proactive learners capable of addressing real-world environmental challenges.

Recommendations:

The study's findings focus on the awareness, understanding, and knowledge of grade 10 learners regarding climate and sustainability. The study recommendations include strengthening the conceptual understanding of climate change and sustainability, reinforcing instructions on key concepts such as renewable and non-renewable energy, and enhancing the scientific principles of sustainability, which have lower mean scores among the respondents. Integrate the interactive and visual learning materials, such as videos, infographics, and simulations, to help the students better grasp abstract or complex ideas. Provide practical applications and daily sustainable habits, promote a school-wide project for sustainability initiatives such as waste segregation, energy-saving campaigns, gardening, and water resource management, and encourage the learners to form habits and apply sustainable practices in real life. Embed carbon footprint reduction activities in classroom tasks, allowing students to monitor and reflect on their behaviors. Incorporate social justice and the global impacts of climate change on marginalized communities.

Moreover, enhancing student engagement through project-based learning (PBL) is utilized in science and interdisciplinary subjects to deepen the understanding and application of climate–related issues. Provide the student opportunities to present their projects to the school and community, which can also boost their confidence and communication skills in discussing sustainability. Conduct the targeted support and follow-up activities for learners who showed a neutral response or low confidence in understanding design, and conduct a remedial session on peer mentoring to provide additional guidance. Conduct formative assessments, such as journals and mini-projects, to continue their growth. Involve the parents and community organizations in climate awareness campaigns and school projects to extend learning beyond the classroom. Partner with environmental agencies and NGOs to host talks and workshops for learners, exposing them to real-world sustainability efforts.

Lastly, integrate climate change and sustainability across the curriculum, and engage students in extracurricular activities in English, Mathematics, Science, and Araling Panlipunan to deepen their understanding.

Compliance with ethical standards

Acknowledgments

I sincerely thank Ms. Lerma V. Pena, the school principal at General Emilio Aguinaldo National High School, Division of Imus City, Province of Cavite, for her generous support in conducting this research. Her cooperation and support significantly contributed to the depth and quality of the study.

Special thanks to the Grade 10 learners from the 2024-2025 batch at General Emilio Aguinaldo National High School who participated in this study, demonstrating their interest and showcasing their talents to promote climate sustainability in science education. They participate in a deep investigation of the study. Their willingness to share their insights and experiences was an instrument in shaping the findings of this study. With their enthusiasm for science subjects, this research becomes possible. Their contributions are deeply appreciated and acknowledged.

Disclosure of conflict of interest

We, Marinel Ramilo Gara, Alyssa Julia A. Inguillo-Topacio, and Florence Mae F. Dela Cruz, the authors of this manuscript, currently affirm that there are no conflicts of interest associated with the content of this research. We confirm that this

study was conducted unbiasedly, free from any financial or personal associations that could influence the interpretation of the results or the portrayal of the findings. In the event of any future conflicts of interest, we commit to promptly disclosing them.

Statement of ethical approval

This research study was conducted in compliance with the ethical standards set by the Department of Education and institutional research guidelines. Prior to the commencement of the study, formal approval was obtained from the Schools Division Office of Imus City, and the school administration of General Emilio Aguinaldo National High School. The study adhered to the Basic Education Research Agenda and DepEd Order guidelines regarding ethical conduct and the protection of research participants.

As the participants involved were minors, informed consent from parents / guardians and assent from student participants were secured before data collection. Participation was voluntary, and participants were informed of their rights to withdraw from the study without any penalty. All data collected were treated with strict confidentiality and anonymity, ensuring that no personal identifiers were disclosed at any stage of the research process.

No physical, psychological, or academic risk was imposed on the study participants. The research focused solely on academic experience related to project-based learning and climate education, posing minimal risk and promoting educational benefits. The conduct of this study adhered to the ethical principles of respect for other person, beneficence and justice.

Statement of informed consent

Learner participants were informed that participation was voluntary and that they could withdraw without repercussions to their relationship with the researchers or the institution. Confidentiality measures were explained, ensuring participants that their data would be anonymized, stored securely, and used solely for the purposes of this study. I addressed participant queries comprehensively, ensuring their understanding and allowing them ample time to make a decision. Documented permission was acquired from each participant before any study-related processes were initiated.

I recognize my responsibility to adhere to ethical guidelines, ensure proper documentation of informed consent, and comply with research regulations involving human subjects.

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