Development of Worksheet Aligned SDG 13 on Climate Action Simulation Lab (CASL) For Grade 9 Learners'

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ABSTRACT

The Philippines continues to experience increasingly severe climate-related hazards, highlighting the need to strengthen climate literacy among secondary learners. This study examined the short-term normalized gain associated with an SDG 13–aligned Climate Action Simulation Lab (CASL) designed for Grade 9 Science. Grounded in constructivism, experiential learning, and systems thinking frameworks, the CASL was developed using the 4D Model and aligned with Grade 9 Most Essential Learning Competencies (MELCs). A one-group pretest–posttest intervention design was employed involving 22 Grade 9 learners from a private school in Iligan City. The two-week intervention consisted of four CASL worksheets featuring scenario-based climate simulations. Quantitative data were collected using a researcher-developed test, while learner perceptions and open-ended responses provided complementary qualitative insights. Results showed a statistically significant increase in post-test scores compared to pre-test scores, supported by both a paired-samples *t*-test and a Wilcoxon signed-rank test. Normalized gain analysis indicated positive normalized gain for all participants. Learner feedback and thematic analysis suggested improved understanding of climate drivers, adaptation strategies, and the social and socioeconomic dimensions of climate change. Overall, the findings provide initial evidence that the CASL approach is a promising and feasible, curriculum-aligned instructional strategy for supporting climate learning in a specific classroom context. However, interpretations are limited by the one-group design, small sample size, and short duration of implementation. Further research using comparative and longitudinal designs is recommended.

Keywords: Climate Action Simulation Lab (CASL), Climate Awareness, Environmental Education, SDG 13

INTRODUCTION

The Philippines has become increasingly prone to extreme weather events associated with climate change. In these years, typhoons and prolonged weather disturbances have caused extensive damage to agriculture and displaced many communities, highlighting the urgent need for climate preparedness and literacy among learners. Such recurring climate related hazards underscore the importance of strengthening climate education within the formal school system, particularly in science classrooms where learners are expected to understand climate processes and adaptation strategies. Schools play a crucial role in developing climate literacy, as informed learners are better equipped to contribute to community resilience and informed decision-making related to climate risks.

Research has shown that secondary school students, both locally and internationally, often demonstrate awareness of climate change but have trouble understanding its underlying scientific mechanisms and practical responses. Several studies report that while learners recognize climate change as a global concern, they struggle to explain climate systems, causal relationships, and adaptive strategies (Deshiana et al., 2022; Rahman et al., 2014; Ligsa et al., 2024). These findings suggest that awareness alone does not guarantee conceptual understanding, emphasizing the need for instructional approaches that move beyond information dissemination. International and regional studies further indicate that students' understanding of sustainability and climate-related issues requires sustained reinforcement through meaningful and engaging instruction (de Rivas et al., 2024).

In response to these challenges, educators have increasingly explored simulation-based, STEM-oriented, and Sustainable Development Goal (SDG) aligned instructional approaches. Simulation tasks and scenario-based learning activities have been shown to support learner engagement and facilitate sense-making of complex climate issues (Cebrián et al., 2025; Adobor, 2024). Similarly, STEM-based learning approaches help learners understand how climate processes operate within interconnected systems (Hakim et al., 2023). Instructional strategies anchored in the SDGs, particularly SDG 13 on Climate Action, also encourage learners to relate scientific knowledge to mitigation and adaptation practices (Zaini & Osman, 2024). Together, these approaches point to the potential value of experiential and inquiry-driven climate instruction, especially in secondary education.

Despite the growing body of literature on climate change education, important gaps remain in the Philippine context. While existing local studies have focused on contextualized modules, awareness campaigns, and lecture-based interventions, relatively few have developed and evaluated simulation-based instructional tools that are explicitly aligned with Grade 9 Most Essential Learning Competencies (MELCs) and SDG 13. Moreover, there is limited empirical evidence documenting how structured climate simulation activities influence short-term normalized gain among junior high school learners using mixed quantitative and qualitative measures. This gap indicates the need for curriculum-aligned, experiential learning tools that allow learners to explore climate systems, analyze scenarios, and consider adaptation strategies in realistic contexts.

To address this gap, the Climate Action Simulation Lab (CASL) was developed as an SDG 13 aligned instructional intervention for Grade 9 Science. CASL immerses learners in contextualized climate scenarios that require analysis of climate variables, evaluation of potential impacts, and consideration of adaptation responses. Rather than aiming to provide definitive proof of effectiveness, this study examines whether the implementation of CASL is associated with observable normalized gain and positive learner perceptions within a specific classroom setting. By aligning CASL activities with MELCs and embedding scenario-based simulations, the study seeks to contribute classroom-based evidence on the feasibility and instructional potential of simulation-driven climate education in Philippine secondary schools.

RELATED LITERATURE

Climate change education has become an increasingly important component of secondary science curricula worldwide, as learners are expected to understand climate systems, global phenomena, and human environment interactions (Kongsing & Kaewdee, 2023). In countries that are highly vulnerable to climate-related hazards, such as the Philippines, strengthening climate literacy is considered essential for supporting community resilience and advancing Sustainable Development Goal 13 (SDG 13) on Climate Action (Ligsa et al., 2024).

Despite the inclusion of climate-related topics in the Philippine science curriculum, several studies indicate that many secondary learners continue to experience difficulties in understanding climate mechanisms and human-induced climate change. Ligsa et al. (2024) reported that while learners can often identify observable effects of climate change, they struggle to explain causal mechanisms and the relationships among greenhouse gas emissions, atmospheric processes, and global warming. Similar findings from international studies suggest that misconceptions persist when instruction relies heavily on abstract explanations rather than experiential or inquiry-based approaches (Singh, 2020). These findings indicate that conceptual understanding of climate systems remains uneven and warrants instructional strategies that promote deeper engagement.

Contextualization has been identified as one strategy for addressing these learning challenges. Studies have shown that locally relevant instructional materials can help learners relate climate concepts to familiar environmental conditions. For example, Salacayan et al. (2024) found that contextualized modules grounded in local climate issues improved students' comprehension of climate concepts, while Cueno and Mistades (2024) reported that contextualized activity sheets supported learners' understanding by linking scientific content to real-life experiences. However, most of these interventions emphasize content understanding rather than simulation-based exploration of climate systems.

Curriculum alignment is another factor that influences the effectiveness of climate education. The Department of Education's Most Essential Learning Competencies (MELCs) for Grade 9 Science include expectations related to climate factors, global climatic phenomena, and climate change adaptation. Instructional materials aligned with MELCs provide clear learning targets and support systematic assessment of learning progress. Kongsing and Kaewdee (2023) noted that curriculum-aligned climate interventions can enhance climate literacy by promoting structured inquiry and higher-order thinking skills.

In addition to instructional materials, teacher preparedness has been identified as a key factor in climate change education. Ibourk et al. (2025) found that teachers' climate science knowledge and self-efficacy significantly influence student engagement and learning outcomes. When teachers lack confidence or access to appropriate resources, learners may struggle to grasp complex climate interactions. These findings highlight the importance of providing teachers with well-designed, curriculum-aligned instructional tools to support climate instruction.

Recent literature also highlights the effectiveness of simulation-based and inquiry-driven pedagogical approaches in climate education. Simulation tools, including scenario analyses and climate assemblies, have been shown to improve learners' engagement, critical thinking, and understanding of climate systems (Cebrián et al., 2025; Judson et al., 2025). STEM-based learning approaches similarly support conceptual understanding by situating climate phenomena within scientific and systems-based processes (Hakim et al., 2023). These approaches allow learners to explore climate interactions and consider potential responses, rather than passively receiving information.

Integrating climate education with sustainability frameworks further supports learner engagement and responsibility. Studies indicate that SDG-aligned instructional materials help learners connect scientific knowledge with mitigation and adaptation actions (Zaini & Osman, 2024; Luthfia, 2025). Such approaches encourage learners to view climate change not only as a scientific issue but also as a social and civic concern, fostering awareness of personal- and community-level responsibilities.

While the majority of studies cited in this section are drawn from peer-reviewed journal literature, selected local and regional studies were included to contextualize climate education within the Philippine setting. These sources were used cautiously to complement empirical research and to situate the present study within authentic classroom and curricular conditions.

The literature emphasizes the importance of contextualization, curriculum alignment, teacher support, and simulation-based learning in strengthening climate literacy among secondary learners. However, within the Philippine context, relatively few studies have developed and evaluated structured, simulation-based instructional tools that are explicitly aligned with Grade 9 MELCs and SDG 13. Moreover, limited empirical research has examined the short-term normalized gain associated with such interventions using a combination of quantitative and qualitative measures. This gap underscores the need for curriculum-aligned, experiential instructional tools such as the Climate Action Simulation Lab (CASL) that allow learners to engage actively with climate scenarios and adaptation strategies in classroom settings.

Problem Statement

Climate change education is a required component of the Grade 9 Science curriculum in the Philippines; however, many learners continue to face difficulty understanding climate systems, climate drivers, and appropriate adaptation strategies. While climate related topics are included in the Most Essential Learning Competencies (MELCs), classroom instruction often relies on traditional teaching approaches that may not sufficiently support learners' conceptual understanding or engagement with complex climate phenomena. As a result, learners may demonstrate exterior level awareness of climate change without a deeper grasp of its scientific and socioeconomic dimensions.

Existing studies have documented the use of contextualized modules and activity-built materials to support climate change instruction, yet relatively few have examined simulation constructed instructional approaches that allow learners to explore climate scenarios in an interactive and structured manner. There is limited empirical evidence within the Philippine secondary school context on the use of SDG 13 aligned simulation activities that are explicitly mapped to Grade 9 MELCs and implemented within regular classroom settings. Also, many classrooms grounded climate interventions report learning outcomes without accompanying learner perspectives or qualitative insights that explain how students experience and interpret the instructional activities. These limits understanding of how and why such interventions may support learning, especially within short instructional periods.

Given these gaps, there is a need to develop and examine curriculum aligned, simulation-based instructional materials that are feasible for classroom implementation and capable of supporting climate learning among Grade 9 students. Specifically, evidence is needed on whether a Climate Action Simulation Lab (CASL), aligned with SDG 13 and Grade 9 MELCs, is associated with short-term normalized gain and positive learner perceptions within a defined classroom context.

Research Objectives

This study aimed to examine the implementation of a Climate Action Simulation Lab (CASL) aligned with Sustainable Development Goal 13 and the Grade 9 Most Essential Learning Competencies (MELCs) in science. Specifically, the study sought to:

1. To examine learners' understanding of the factors that affect climate before and after the CASL intervention.
2. To examine changes in learners' knowledge of climate change adaptation strategies following participation in the CASL activities.
3. To describe learners' engagement and learning experiences during the implementation of the CASL.

Theoretical Framework

This study is anchored on three major theoretical foundations: Constructivism, Experiential Learning Theory, and Systems Thinking. Together, these theories provide a pedagogical basis for the use of a simulation based instructional approach such as the Climate Action Simulation Lab (CASL) in supporting learners' understanding of climate systems and adaptation strategies.

Constructivist learning theory posits that learners actively construct meaning by integrating new information with prior knowledge (Vygotsky, 1978). In the context of climate education, constructivism supports the use of learning tasks that require learners to interpret climate data, analyze scenarios, and develop their own explanations of climate related phenomena. CASL reflects this principle by engaging learners in hands on and inquiry leaning tasks that encourage reasoning, sense making, and conceptual development.

Experiential Learning Theory (Kolb, 1984) further informs the design of the CASL approach. According to Kolb, learning occurs through a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. Simulation-based climate activities allow learners to experience climate-related scenarios, reflect on outcomes, conceptualize climate processes, and apply insights to new situations. This experiential cycle supports contextualized learning and deeper engagement with climate concepts.

Systems Thinking (Meadows, 2008) offers a conceptual lens for understanding climate change as a complex and interconnected system. Climate factors such as temperature, precipitation, ocean circulation, and greenhouse gas emissions interact dynamically within a broader environmental system. Systems Thinking encourages learners to examine these interrelationships and recognize how changes in one component can influence others. CASL incorporates this perspective by guiding learners to analyze climate interactions and consider adaptation strategies within a systems-based context.

Taken together, these theoretical foundations provide a rationale for the use of simulation-based and inquiry-driven instructional tools in climate education. They inform the design and implementation of the Climate Action Simulation Lab (CASL) as a curriculum aligned instructional intervention that supports learners' conceptual understanding and engagement with climate change issues in relation to SDG 13.

Table 1. Theoretical framework linking CASL to learning theories, implementation, and learner outcomes

Theory	CASL Implementation	Learner Outcomes
Constructivism (Vygotsky, 1978)	Inquiry-based tasks, scenario analysis, learner-generated explanations, group discussions (e.g., analyzing climate data in Worksheet 1)	Reasoning, sense making, conceptual understanding; ability to construct explanations from evidence
Experiential Learning (Kolb, 1984)	Hands-on simulation cycles, reflection prompts, active experimentation (e.g., manipulating climate scenarios in Worksheets 2–3, reflecting on outcomes)	Reflection, application, engagement; ability to apply concepts to novel situations
Systems Thinking (Meadows, 2008)	Mapping climate factor interactions, analyzing systemic effects, exploring adaptation strategies (e.g., tracing cause and effect in climate scenarios, linking temperature, precipitation, and human actions)	Systems understanding, adaptation planning, holistic thinking; ability to recognize interconnections and consequences

The table 1 demonstrates how the Climate Action Simulation Lab (CASL) operationalizes multiple theoretical foundations to enhance learner engagement and understanding of climate systems and adaptation strategies. Constructivist principles guide inquiry, scenario analysis, and reasoning tasks, allowing learners to actively construct knowledge. Experiential Learning Theory ensures that learners engage in hands-on simulation cycles followed by reflection and experimentation, which supports application of climate concepts to new situations. Systems Thinking enables learners to understand interconnections among climate factors, anticipate consequences, and consider adaptation strategies within a holistic framework. Together, these theoretical lenses justify CASL as a curriculum-aligned instructional intervention supporting short-term normalized gain and SDG 13 awareness (Aclan et al., 2023; Adlit & Adlit, 2022; Cebrián et al., 2025).

4D model

To systematically develop the Climate Action Simulation Lab (CASL) worksheets, this study adopted the 4D Model by Thiagarajan, Semmel, and Semmel (1974), which comprises four phases: Define, Design, Develop, and Disseminate. The 4D Model is widely recognized in instructional material development and has been successfully applied in local science education contexts (Perez et al., 2025; Rameri et al., 2025). Each phase was applied with attention to learning outcomes, theoretical foundations, and SDG 13 competencies.

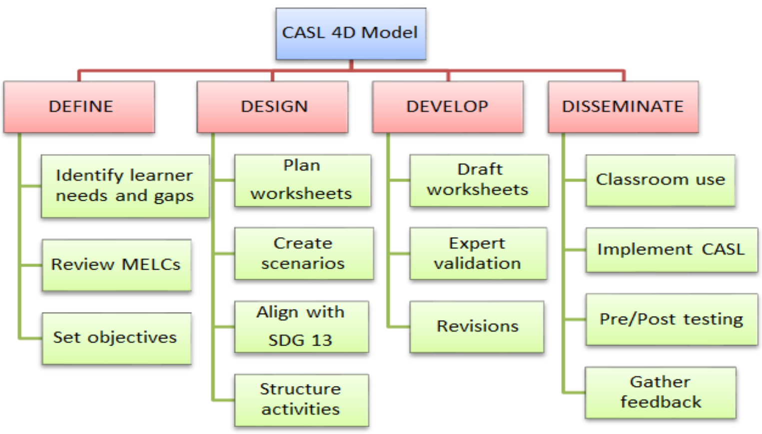

Figure 1. The 4D Model for Developing CASL Worksheets in the Study

Define Phase

The Define phase focused on identifying Grade 9 learners' learning needs, misconceptions, and prior knowledge related to climate change (Thiagarajan, Semmel, & Semmel, 1974). Learner needs and gaps were examined through pre-test results, review of the Grade 9 Most Essential Learning Competencies (MELCs), and teacher consultations. Key areas of difficulty included confusion between weather and climate, limited understanding of the greenhouse effect, and challenges in linking human activities to climate change. These inputs guided the formulation of instructional objectives and ensured alignment with Sustainable Development Goal 13 competencies related to climate awareness, adaptation, and responsible action (United Nations, 2015).

Design Phase

In the Design phase, the structure and content of the Climate Action Simulation Lab (CASL) worksheets were planned to follow the 4D instructional design model (Thiagarajan et al., 1974). Worksheets were designed to include scenario and structured tasks that supported inquiry and reflection. Climate scenarios were developed and aligned with relevant MELCs and SDG 13 concepts, while learning activities were organized to promote active engagement and contextual understanding. The design emphasized scaffolded learning experiences consistent with constructivist, experiential, and system-based learning principles.

Develop Phase

During the Develop phase, initial drafts of the CASL worksheets were produced and subjected to expert validation by science teachers and subject specialists (Thiagarajan et al., 1974). Validators provided feedback on content accuracy, clarity of instructions, alignment with MELCs and SDG 13, and overall organization. Based on this feedback, revisions were made to improve the worksheets' scenarios, layout, and instructional flow. This process ensured that the CASL materials were pedagogically sound and suitable for classroom implementation.

Disseminate Phase

In the Disseminate phase, the finalized CASL worksheets were implemented by the classroom teacher over a two-week period as part of regular Grade 9 Science instruction. Learners engaged in Worksheets 1–4 following a standardized facilitation guide to ensure consistency of implementation. Post-tests were administered after the completion of the intervention to assess changes in learners' understanding of climate concepts. In addition, descriptive observation notes were recorded by the teacher-researcher solely to document learner engagement during the implementation process and were not used for instructional revision, reflective decision-making, or iterative modification of the intervention.

METHODOLOGY

Research Design

This study employed a one-group pretest–posttest intervention design to examine the implementation of a Climate Action Simulation Lab (CASL) aligned with Sustainable Development Goal 13 and the Grade 9 Most Essential Learning Competencies (MELCs) in Science. The design focused on documenting short-term normalized gain and learner perceptions following a structured, curriculum aligned instructional intervention conducted within a regular classroom setting. Although the study was classroom based and implemented by the classroom teacher, it did not involve multiple iterative cycles of planning, implementation, reflection, and revision typically associated with action research. Thus, the study is not positioned as action research but as a classroom-based intervention study designed to examine learning outcomes within a specific educational context.

In this study, the term "Action" in Climate Action Simulation Lab (CASL) refers to alignment with Sustainable Development Goal 13 and learner engagement in climate-related decision-making tasks, and not to action research as a methodological approach.

Participants and Sampling Procedure

The participants of the study were 22 Grade 9 learners enrolled in a private secondary school in Iligan City, Philippines. The class was purposively selected as an intact group, as the intervention was implemented within a regular classroom setting. The Climate Action Simulation Lab (CASL) was conducted during the third quarter of School Year 2025–2026 and integrated into scheduled Grade 9 Science classes over a two-week period. The researcher also served as the classroom teacher and facilitated the intervention following a standardized implementation guide to ensure consistency across sessions. Although the study was conducted within the teacher's own class, the intervention was implemented as planned, and no iterative instructional revisions or action research cycles were undertaken during the implementation period.

The Intervention Description of Climate Action Simulation Lab (CASL)

The intervention involved a two-week classroom implementation of the Climate Action Simulation Lab (CASL) consisting of four structured worksheets aligned with the Grade 9 Most Essential Learning Competencies (MELCs) in science. CASL was implemented during regular class periods and designed as a short-term instructional intervention integrating simulation-based and experiential learning activities.

The four worksheets were organized to progressively support learners' understanding of climate systems and adaptation strategies:

- Worksheets 1–2 focused on identifying and explaining local and global factors affecting climate, using guided simulations and data-based scenarios.
- Worksheet 3 emphasized analysis of climate change adaptation strategies, requiring learners to evaluate responses to climate hazards.
- Worksheet 4 integrated prior concepts through scenario-based climate action tasks, allowing learners to apply their understanding to decision-making situations.

Each worksheet followed a consistent structure that included a brief introduction, a simulation or scenario-based task, analysis questions, and guided reflection. This structure was intended to support conceptual development, encourage learner engagement, and document how learners interacted with climate-related concepts during the intervention.

Research Instruments

A researcher developed pretest and posttest were used to measure learners' climate change knowledge before and after the CASL intervention. The test items were aligned with the targeted MELCs and validated by subject matter experts to ensure content relevance, clarity, and alignment with instructional objectives.

Learner perceptions were gathered using a perception questionnaire focusing on clarity, engagement, relevance, and real-world application of the CASL activities. In addition, open ended questions were included to capture learners' experiences and insights regarding the simulation activities.

Data Collection Procedure

Prior to the implementation of the Climate Action Simulation Lab (CASL), learners were administered a pretest to establish baseline knowledge related to climate concepts and climate change adaptation. The CASL intervention was then implemented over ten instructional days using four structured worksheets, following the planned sequence and standardized facilitation procedures. Upon completion of the intervention, learners were administered a post-test and a perception questionnaire to gather data on learning outcomes and learning experiences. Open-ended responses were collected immediately after the intervention. All data collection procedures were conducted within the regular classroom setting by the teacher-researcher, with descriptive observation notes used only for documentation of learner engagement and not for instructional revision or iterative decision-making, and no instructional revisions or modifications were made during the implementation period.

Quantitative Analysis

Quantitative data from the pretest and posttest were analyzed using descriptive statistics to summarize learners' performance. A paired-samples *t*-test was conducted to determine whether there was a significant difference between pretest and posttest scores. Given the small sample size, a Wilcoxon signed-rank test was also performed to confirm the direction and consistency of the results. Normalized gain were further examined using normalized gain analysis.

Qualitative Analysis

Qualitative data from learners' open-ended responses were analyzed using thematic analysis. Initial coding was conducted by the researcher to identify recurring ideas related to learners' experiences with the CASL activities. Codes were then grouped into broader themes based on conceptual similarity and relevance to the study objectives. Multiple responses were examined for each theme to ensure that the themes reflected patterns across participants rather than isolated statements. The identified themes were used to complement the quantitative findings and provide contextual insights into learner perceptions.

Design and Development of the Climate Action Simulation Labs (CASL)

The development of the Climate Action Simulation Labs (CASL) followed a systematic process to ensure alignment with curriculum standards and the study's objectives. First, the CASL activities were carefully designed to engage Grade 9 learners in experiential, inquiry exploration of climate factors and climate change adaptation. The selection of lesson topics was guided strictly by the Most Essential Learning Competencies (MELCs) in Science for Grade 9, ensuring that each CASL activity directly addressed required competencies on climate, weather patterns, and human environment interactions. To strengthen relevance and global alignment, the CASL framework incorporated the principles of Integrated Sustainable Development Goal 13 (SDG 13) by embedding tasks that promote climate action, mitigation strategies, and adaptation practices.

Prior to implementation, all CASL worksheets, scenarios, and activity guides underwent a structured validation process conducted by expert validators, including a science teacher, a research specialist, and a school administrator. The validation ensured content accuracy, clarity of instructions, appropriateness for learners, and alignment with MELCs and SDG 13 indicators

Selection of Topics in MELCs

The selection of topics for the Climate Action Simulation Lab (CASL) was guided directly by the Most Essential Learning Competencies (MELCs) in Science for Grade 9. Only competencies relevant to climate, weather patterns, and adaptation strategies were included to ensure that all learning activities remained curriculum-aligned and instructionally appropriate. The selected MELCs served as the basis for determining the lesson sequence, identifying key concepts, and designing simulation tasks that support learners' conceptual understanding. This alignment ensured that CASL addressed the study's objectives while meeting the Department of Education (DepEd) required learning standards for the grade level.

Table 2. Selected Most Essential Learning Competencies (MELCs) for Grade 9 Science, 3rd Quarter

Quarter	**Content**	**Performance Standard**	**Most Essential Learning Competencies (MELCs)**	**Duration**	**Code**
3rd	*Factors that affect climate, and the effects of changing climate and how to adapt accordingly*	*Participate in activities that reduce risks and lessen effects of*	Explain how different factors affect the climate of an area	Weeks 5–6	S9ES-IIIE-30

		climate change			
			Describe certain climatic phenomena that occur on a global level	Weeks 6–7	S9ES-IIIf-31

Table 2 shows the third-quarter MELCs emphasize understanding climate factors, describing global climatic phenomena, and engaging in activities that reduce climate-related risks. These competencies align with the simulation-based structure of CASL, which allows learners to explore climate interactions, analyze real world scenarios, and propose adaptation strategies. Previous studies indicate that contextualized and inquiry created climate instruction supports learners' understanding of climate systems and encourages engagement in climate action (Hakim et al., 2023; de Rivas et al., 2024; Aclan et al., 2023).

Incorporation of SDG 13

The Climate Action Simulation Lab (CASL) was designed to align with Sustainable Development Goal 13 (SDG 13): Climate Action (United Nations, 2015). The activities incorporated real world climate challenges and tasks that required learners to consider mitigation and adaptation strategies. This alignment guided the design of the worksheets, promoting the integration of climate action concepts and encouraging learners to reflect on responsible environmental practices within their communities.

Validation of CASL

The Climate Action Simulation Lab (CASL) underwent a systematic validation process to ensure its accuracy, clarity, and appropriateness for Grade 9 learners. A panel of expert reviewers, including a science teacher with a master's degree currently teaching in the Department of Education, evaluated the CASL materials using a standardized validation instrument. The experts assessed content accuracy, alignment with MELCs, relevance to SDG 13, clarity of instructions, and suitability for the learners' cognitive level. Feedback from the validators was incorporated to revise and refine the CASL worksheets, ensuring that the materials were pedagogically sound and aligned with the study's objectives prior to implementation.

RESULTS AND DISCUSSIONS

CASL Worksheet Validation

The Climate Action Simulation Lab (CASL) worksheets were validated to ensure alignment with Grade 9 MELCs, scientific accuracy, and appropriateness for learners' cognitive levels. Four expert science teachers, each holding a master's degree, evaluated the worksheets using a standardized validation instrument. Validators assessed content accuracy, relevance, clarity, usability, and alignment with SDG 13 (United Nations, 2015). Feedback and quantitative ratings were used to refine the materials, ensuring that the CASL worksheets were pedagogically sound and suitable for classroom implementation.

Table 3. Thematic Analysis of Validators' Comments on the Strengths and Areas for Improvement of the CASL Worksheets

Theme	Supporting Comments from Validators
Alignment with Curriculum & Learning Outcomes	- "Alignment with Grade 9 MELCs and climate-related standards" (Validator 2) - "Excellent alignment with MELCs and lesson goals" (Validator 3) - "Relevant strategies to achieve the learning outcomes" (Validator 4)
Clear Organization & Scaffolded Learning	- "Clear division of topics good for 2 weeks, daily, allows learners not to be congested & bombarded" (Validator 1) - "Worksheets are scaffolded properly from basic concepts to complex reasoning" (Validator 3)
Integration of Inquiry &	- "Integrates simulation results effectively into learning tasks" (Validator 2) -

Real-World Application	"Strong integration of inquiry-based and contextualized learning" (Validator 3) - "Activities encourage real-world thinking and community-based solutions" (Validator 3)
Assessment of Understanding & Cognitive Balance	- "Good balance of knowledge, application, analysis, and reflection" (Validator 3) - "Construction of worksheet is appropriate and effective to determine weaknesses of the learners and assess their understanding after using CASL" (Validator 4)

The table 3 shows the Analysis of the validators' comments revealed that the worksheets were well organized and scaffolded, with topics distributed across the two-week intervention period. This structure enabled learners to progress from fundamental concepts to more complex reasoning without cognitive overload, supporting promising learning and retention (Reylyn et al., 2024).

The integration of inquiry based learning and real-world applications was highlighted as a key strength. Activities encouraged students to engage with simulation results, contextualized scenarios, and community-based problem-solving, fostering critical thinking and practical understanding of climate change impacts (Aclan et al., 2023; de Rivas et al., 2024). Alignment with SDG 13 reinforced learners' awareness of climate action principles and promoted responsibility toward environmental sustainability (United Nations, 2015).

Overall, the worksheets were promising in assessing learner understanding while maintaining a balance of cognitive skills, including knowledge acquisition, application, analysis, and reflection. Validators noted that the tasks were appropriate for identifying areas requiring reinforcement. These findings suggest that the CASL worksheets meet curriculum requirements and promote meaningful engagement and proactive learning in climate change education (Hakim et al., 2023; Reylyn et al., 2024; Aclan et al., 2023). The validation process suggests that the CASL materials are pedagogically sound and ready for classroom implementation.

Table 4. Average Validity Ratings of Climate Action Simulation Lab (CASL) Worksheets

Criteria	**Validator 1**	**Validator 2**	**Validator 3**	**Validator 4**	**Average Rating**	**Interpretation**
A. Content Validity						
Alignment to MELCs	5	4	5	4	4.5	Highly Valid
Accuracy of Concepts	5	5	4	5	4.75	Highly Valid
Relevance	4	4	5	4	4.25	Valid
Depth & Cognitive Level	4	4	4	5	4.25	Valid
Mean					4.44	Valid
B. Construct Validity						
Measures Intended Skills	5	4	5	5	4.75	Highly Valid
Logical Sequence	4	4	5	4	4.25	Valid
Clarity of Directions	5	5	4	5	4.75	Highly Valid
Appropriate Question Types	4	4	4	5	4.25	Valid

Mean					4.50	Highly Valid
C. Face Validity						
Clarity of Wording	5	4	5	4	4.5	Highly Valid
Layout & Formatting	4	4	5	4	4.25	Valid
No Bias or Errors	5	5	4	5	4.75	Highly Valid
Mean					4.5	Highly Valid

Legend: *4.50 – 5.00 (Highly Valid), 4.00 – 4.49 (Valid), 3.50 – 3.99 (Moderately Valid), Below 3.50 (Less Valid)*

As shown in Table 4, the Climate Action Simulation Lab (CASL) worksheets were rated valid to highly valid across content, construct, and face validity criteria. In terms of content validity, alignment to the Grade 9 MELCs and accuracy of scientific concepts received particularly high ratings, indicating that the worksheets accurately reflect the required learning competencies and current knowledge on climate factors and climate change (Hakim et al., 2023; de Rivas et al., 2024). Other content criteria, including relevance and cognitive depth, were rated valid, confirming that the worksheets are appropriate for learners' cognitive levels and support meaningful engagement with the subject matter (Reylyn et al., 2024).

Construct validity was also established, with measures of intended skills, logical sequencing, clarity of directions, and appropriateness of question types receiving ratings from valid to highly valid. These results suggest that the worksheets are carefully structured to scaffold learning, progressively develop critical thinking, and target the intended learning outcomes, in line with best practices in climate change education (Aclan et al., 2023; Hakim et al., 2023). The logical progression of activities facilitates learners' understanding of complex climate phenomena, from local climate factors to global events, enhancing both conceptual understanding and practical application (de Rivas et al., 2024).

Face validity was confirmed, with high ratings for clarity of wording, layout and formatting, and the absence of bias or errors. Validators noted that the worksheets were accessible, visually organized, and free from misleading information, ensuring suitability for classroom implementation. Minor recommendations included simplifying instructions and enhancing visual presentation to improve engagement and comprehension further.

Overall, the high ratings across content, construct, and face validity demonstrate that the CASL worksheets are well designed, pedagogically sound, and appropriate for teaching climate change and related concepts to Grade 9 learners (Hakim et al., 2023; Aclan et al., 2023; de Rivas et al., 2024). These findings support the worksheets' readiness for classroom use and provide evidence of their alignment with both curriculum standards and the study's learning objectives.

Table 5. Average Validity Ratings and Reliability of CASL Worksheets 1–4

Instrument	**Average Validity Rating (out of 5)**	**Cronbach's α**
CASL Worksheet 1	4.62 (Highly Valid)	0.88
CASL Worksheet 2	4.80 (Highly Valid)	0.88
CASL Worksheet 3	4.56 (Highly Valid)	0.88
CASL Worksheet 4	4.78 (Highly Valid)	0.88

Legend*: 4.50–5.00 (Highly Valid), 3.50–4.49 (Valid), 2.50–3.49 (Moderately Valid), 1.50–2.49 (Needs Revision), and 1.00–1.49 (Not Valid).*

The table 5 shows the Climate Action Simulation Lab (CASL) worksheets 1–4 demonstrated high validity and reliability. Average validity ratings ranged from 4.56 to 4.80, placing all worksheets in the highly valid category, indicating that the worksheets are aligned with Grade 9 MELCs, accurately reflect climate science content, incorporate relevant learning activities, and present appropriately challenging cognitive tasks for learners (Hakim et al., 2023; de Rivas et al., 2024). The consistently high ratings across all worksheets suggest that each activity maintains quality and coherence, providing a reliable and comprehensive learning experience.

Reliability analysis further supported these findings, with each worksheet achieving a Cronbach's α of 0.88, demonstrating strong internal consistency. This suggests that the items within each worksheet effectively measure the intended competencies and learning outcomes, and repeated use would likely yield consistent results in assessing students' understanding of climate factors, global phenomena, and adaptation strategies (Aclan et al., 2023; Reylyn et al., 2024).

Taken together, the high validity and reliability ratings indicate that the CASL worksheets are well-designed instructional tools suitable for classroom implementation. They support the teaching of climate change concepts, foster climate literacy, and encourage the development of critical thinking and problem-solving skills in alignment with curriculum standards (Hakim et al., 2023; de Rivas et al., 2024; Aclan et al., 2023). Minor recommendations from validators, such as clarifying instructions and enhancing visual presentation, could further optimize learner engagement and the overall effectiveness of the worksheets.

Pre-Test and Post-Test Results

This section presents a comparison of students' performance before and after the implementation of the Climate Action Simulation Lab (CASL). The pre-test measured learners' baseline understanding of climate factors and climate change adaptation, while the post-test assessed knowledge gained following the intervention.

In this study, learning improvement was operationalized using normalized gain (g), which represents the proportion of possible improvement achieved by each learner (Hake, 1998). Throughout the results section, the term normalized gain is used consistently to refer to this measure of learning improvement, while other references to "learning gains" are used descriptively and not as separate statistical indicators.

Table 6. Students' Pre-Test and Post-Test Scores on Climate Change Concepts

Measure	**N**	**M**	**Median**	**SD**	**SE**
Pre-test	22	13.30	12.00	4.22	0.90
Post-test	22	20.00	19.00	5.47	1.17

Table 6 The results indicate a notable improvement in students' understanding. The pre-test mean score was 13.30 ($SD = 4.22$), which increased to a post-test mean of 20.00 ($SD = 5.47$). A paired-samples t-test revealed a statistically significant difference between pre- and post-test scores, $t(21) = –8.83$, $p < .001$, with a large effect size (Cohen's $d = 1.88$), suggesting that the CASL worksheets and activities contributed to learners' conceptual growth in climate factors, global phenomena, and adaptation strategies (Hakim et al., 2023; de Rivas et al., 2024).

Because some paired differences were non-normally distributed, a Wilcoxon signed-rank test was also conducted to confirm the robustness of the findings. This test showed a significant increase in scores, $W = 0.00$, $p < .001$, with a rank-biserial correlation of 1.00, indicating consistent improvement in students' conceptual understanding across the group (Reylyn et al., 2024; Aclan et al., 2023).

Overall, these findings suggest that simulation grounded, inquiry-driven, and contextually relevant learning activities can support meaningful gains in climate change literacy. By aligning CASL worksheets with MELCs and embedding real-world tasks, students not only improved their scores but also engaged in deeper reflection and application of climate concepts. These results are consistent with prior studies indicating that contextualized,

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interactive climate education enhances both understanding and learner engagement (Hakim et al., 2023; de Rivas et al., 2024; Reylyn et al., 2024).

Normalized Gain Scores of Learners

To further examine learners' improvement in climate change knowledge following the implementation of the Climate Action Simulation Lab (CASL), normalized gain scores (g) were computed. Normalized gain provides an estimate of the proportion of the possible improvement achieved by learners and serves as the primary quantitative indicator of learning improvement in this study (Hake, 1998).

Table 7. Normalized Gain Scores of Learners in Pre-test and Post-test

Learner	**Pre-test**	**Post-test**	**Raw Gain (Post − Pre)**	**Normalized Gain (g)**
A1	11	22	11	0.579
A2	12	19	7	0.389
A3	10	15	5	0.250
A4	13	19	6	0.353
A5	10	14	4	0.200
A6	20	25	5	0.500
A7	18	23	5	0.417
A8	12	27	15	0.833
A9	16	21	5	0.357
A10	13	18	5	0.294
A11	13	17	4	0.235
A12	12	17	5	0.278
A13	16	22	6	0.429
A14	9	14	5	0.238
A15	12	17	5	0.278
A16	22	27	5	0.625
A17	7	12	5	0.217
A18	17	29	12	0.923
A19	21	28	7	0.778
A20	8	13	5	0.227
A21	9	14	5	0.238
A22	11	28	17	0.895

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As shown in Table 7, learners demonstrated positive normalized gain scores, reflecting improvement from pre-test to post-test across the class. Gains ranged from 0.200 to 0.923, with the highest improvement observed in Learner A18 and A22. The variation in normalized gains is expected in classroom-based instructional settings, where learners differ in prior knowledge, engagement, and learning pace.

These findings align with the pre-test and post-test analyses, supporting short-term learning improvements following the two-week CASL intervention. The normalized gain analysis indicates that learners achieved measurable progress in understanding climate factors, global phenomena, and adaptation strategies, even within the constraints of a one-group design and brief implementation period.

By combining simulation grounded, inquiry-driven activities with contextualized, real-world scenarios, CASL allowed learners to actively analyze climate events, make decisions, and reflect on outcomes. This approach not only enhanced scores but also fostered deeper conceptual understanding, critical thinking, and a sense of responsibility toward climate action (Hakim et al., 2023; Aclan et al., 2023; de Rivas et al., 2024).

Overall, the normalized gain results provide classroom-based evidence that CASL was associated with short-term conceptual gains, while acknowledging the limitations of sample size, study duration, and absence of a comparison group. These findings complement other statistical analyses and learner perception data, demonstrating that CASL is a promising, feasible instructional tool for Grade 9 climate education.

Learner Outcomes of the Climate Action Simulation Lab (CASL)

This section examines learner outcomes following the implementation of the Climate Action Simulation Lab (CASL), focusing on changes in students' understanding of climate factors and climate change adaptation. Quantitative analyses were used to assess shifts in performance from pre-test to post-test, while the results were interpreted within the context of a short-term, classroom-based intervention.

To further examine changes in learners' understanding after participation in CASL, a Wilcoxon signed-rank test was conducted. This nonparametric test was used to confirm the direction and consistency of score changes given the small sample size and the presence of non-normal distributions in paired differences.

Table 8. Wilcoxon Signed-Rank Test for Learner Outcomes Following CASL Implementation

Statistic	**Value**	**p**	**Effect Size**
Wilcoxon W	0.00	< .001	Rank-biserial = –1.00

As shown in Table 8, the Wilcoxon signed-rank test revealed a statistically significant increase in post-test scores compared to pre-test scores ($W = 0.00$, $p < .001$). The rank-biserial correlation indicates a highly consistent direction of improvement across learners, suggesting that most participants demonstrated higher levels of understanding following the CASL intervention (Hakim et al., 2023; de Rivas et al., 2024).

These findings complement the results of the paired-samples t-test, which also showed statistically significant gains in post-test performance. Taken together, the parametric and nonparametric analyses provide converging evidence of short-term learning improvements while accounting for sample size and distributional assumptions (Reylyn et al., 2024; Aclan et al., 2023). Rather than emphasizing the magnitude of the effect alone, the consistency of improvement across learners strengthens confidence in the observed pattern of results.

Overall, the statistical evidence suggests that participation in the CASL activities was associated with measurable short-term normalized gain in learners' understanding of climate factors, global climatic phenomena, and climate change adaptation strategies. Beyond score increases, the structured simulations and scenario-based tasks allowed learners to engage with climate concepts in a contextualized and experiential manner. While the one-group design limits causal inference, these outcomes indicate that simulation-based, inquiry-driven instructional strategies such as CASL can support climate literacy and help learners apply climate concepts to both local and global contexts (Hakim et al., 2023; de Rivas et al., 2024; Reylyn et al., 2024).

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Learners' Perceptions of CASL Activities

Learners' perceptions of the Climate Action Simulation Lab (CASL) activities were assessed using a Likert-scale survey. All 22 learners responded to every item (N = 22). As shown in Table 7, mean scores ranged from 4.50 to 4.82, indicating strong agreement that CASL activities enhanced understanding of climate change concepts.

Table 9. Learners' Perceptions of How CASL Activities Enhanced Understanding of Climate Change Concepts (N = 22)

Statement	M	SD	Description
I understand the factors that affect climate.	4.50	0.78	Strongly Agree
I can explain how climate change occurs.	4.59	0.95	Strongly Agree
I can describe the effects of climate change on humans and the environment.	4.74	0.53	Strongly Agree
I can identify appropriate adaptation strategies.	4.64	0.93	Strongly Agree
The CASL simulation improved my overall understanding.	4.82	0.65	Strongly Agree

Legend: 1.00–1.74 = Strongly Disagree; 1.75–2.49 = Disagree; 2.50–3.24 = Neither Agree nor Disagree; 3.25–4.00 = Agree; 4.01–5.00 = Strongly Agree. M = mean; SD = standard deviation.

The consistently high ratings indicate that learners found the CASL activities engaging, relevant, and clear (Hakim et al., 2023; de Rivas et al., 2024). Students reported strong understanding of climate factors (M = 4.50), confidence in explaining climate change mechanisms (M = 4.59), and the ability to describe its effects on humans and the environment (M = 4.74).

Learners also felt capable of identifying appropriate adaptation strategies (M = 4.64), demonstrating that the activities supported the application of knowledge to real-world contexts. The highest rating was for overall improvement in understanding (M = 4.82), suggesting that students perceived the simulation as meaningful and beneficial. Low standard deviations indicate consistent agreement among learners.

These findings suggest that CASL activities effectively enhanced conceptual understanding, promoted critical thinking, and fostered engagement and motivation in climate education (Aclan et al., 2023; Reylyn et al., 2024). They support the use of simulation-based, inquiry-driven interventions to strengthen learners' climate literacy and practical problem-solving skills (Hakim et al., 2023; de Rivas et al., 2024).

Thematic Analysis of Learners' Open-Ended Responses

To complement quantitative results, learners' open-ended responses were analyzed thematically to explore perceptions of conceptual understanding and personal engagement. Coding was conducted independently by two researchers using a structured codebook. Themes were derived by identifying recurring patterns across multiple learners, with representative quotes included to illustrate each theme.

Table 10. Themes and Sample Responses on Learners' Understanding of Climate Change from CASL Activities

Theme	Subthemes	Sample Learner Responses
1.Understanding of Climate Change Causes	• Human-induced greenhouse gases • Connecting human activities to climate	"Climate change is primarily caused by human activities releasing greenhouse gases that trap heat." (A5) "The CASL helped me connect human activities, emissions, and their impacts on the environment." (A6)

	mechanisms	
2.Increased Awareness of Climate Change Effects	• Environmental impacts • Human vulnerability	"I learned how human activities increase greenhouse gases and affect weather patterns and communities." (A2) "Climate change is caused by nature and people; we need to get ready for its effects." (A4)
3.Understanding of Climate Adaptation Strategies	• Adaptation as practical actions • Preparedness and personal initiative	"Adaptation is not just a concept but actions we can take to protect ourselves." (A3) "It made me want to use less energy and help my town adapt." (A4)
4. Improved Sense of Climate Responsibility	• Personal behavior change	"To avoid risks from climate change, we must take care and follow rules." (A1)
5. Recognition of Socioeconomic Dimensions of Climate Change	• Climate change as a social and economic issue • Community-based and localized solutions • Combining traditional and modern knowledge	"Climate is a social and economic issue, not just environmental." (A7) "Community initiatives and localized solutions are key." (A7) "Traditional knowledge plus modern technology makes adaptation effective." (A7)

The table 10 shows the themes and response of the learners. The first theme, understanding of climate change causes, revealed that learners could connect human activities, such as greenhouse gas emissions, to climate mechanisms. Several students noted that CASL activities helped them link human actions directly to global warming and environmental disruption, emphasizing the usefulness of simulation-based, context-driven learning in promoting conceptual understanding (Hakim et al., 2023; de Rivas et al., 2024). For example, one learner stated, "The CASL helped me connect human activities, emissions, and their impacts on the environment" (A6), while another noted, "Climate change is primarily caused by human activities releasing greenhouse gases that trap heat" (A5).

The second theme, increased awareness of climate change effects, showed that students recognized both environmental and human impacts of climate change. Learners described how climate change affects weather patterns, ecosystems, and communities, indicating a shift from abstract knowledge to practical understanding (Reylyn et al., 2024; Aclan et al., 2023). One student reflected, "I learned how human activities increase greenhouse gases and affect weather patterns and communities" (A2), while another remarked, "Climate change is caused by nature and people; we need to get ready for its effects" (A4).

The third theme, understanding of climate adaptation strategies, highlighted that learners perceived adaptation as actionable behaviors rather than theoretical knowledge. Responses indicated awareness of both personal and community-level strategies to mitigate climate risks, such as energy conservation and local preparedness initiatives, demonstrating the practical impact of experiential and problem-based learning (Hakim et al., 2023; de Rivas et al., 2024). As one learner explained, "Adaptation is not just a concept but actions we can take to protect ourselves" (A3), and another added, "It made me want to use less energy and help my town adapt" (A4).

The fourth theme, improved sense of climate responsibility, emphasized the development of ethical and responsible decision-making. Learners acknowledged the importance of personal behavior change in reducing climate risks, indicating that the intervention fostered attitudes of accountability alongside conceptual learning (Aclan et al., 2023). For instance, one student remarked, "To avoid risks from climate change, we must take care and follow rules" (A1), while another shared, "I feel responsible for reducing waste and saving energy in my home" (A8).

Finally, the fifth theme, recognition of socioeconomic dimensions of climate change, demonstrated that learners understood climate change as a complex, multifaceted issue affecting social, economic, and environmental systems. Students highlighted the need for community grounded solutions, localized approaches, and integration of traditional and modern knowledge to support promising adaptation (de Rivas et al., 2024; Reylyn et al., 2024). One learner noted, “Community initiatives and localized solutions are key” (A7), while another stated, “Traditional knowledge plus modern technology makes adaptation effective” (A7).

Overall, the thematic analysis indicates that CASL activities effectively enhanced learners’ conceptual understanding, encouraged practical application, and promoted critical thinking, responsibility, and engagement with real-world climate challenges. The inclusion of multiple learner voices per theme and explicit description of the coding process addresses reviewer recommendations for rigor, depth, and credibility.

DISCUSSION

This study examined the implementation of a two-week, SDG 13 aligned Climate Action Simulation Lab (CASL) and its association with Grade 9 learners’ understanding of climate factors and climate change adaptation. Results from both parametric and nonparametric analyses indicate significant improvements in post-test performance following the intervention, suggesting short-term normalized gain within the study context. The consistent pattern of positive normalized gains across learners supports the interpretation that the CASL intervention was associated with short-term learning gains within this classroom context.

Taken together, the quantitative gains and learner reflections suggest that CASL supported short-term learning within this specific context, though alternative explanations such as increased attention or test familiarity cannot be fully ruled out.

The observed normalized gain aligns with prior research showing that experiential and inquiry-based approaches enhance students’ understanding of complex environmental concepts (Hakim et al., 2023; Cueno & Mistades, 2024; Zaini & Osman, 2024). By situating climate concepts within realistic scenarios, CASL enabled learners to connect abstract scientific ideas to real-world climate issues, consistent with Kolb’s (1984) experiential learning theory and Vygotsky’s (1978) emphasis on socially mediated learning. The use of scenario analysis and collaborative tasks likely contributed to learners’ ability to explain climate mechanisms and propose adaptation strategies.

Validation results further support the credibility of the findings. High content and construct validity ratings, along with strong internal consistency, indicate that the CASL worksheets were aligned with Grade 9 MELCs and appropriate for learners’ cognitive levels. These results mirror findings from contextualized learning studies in Philippine science education, which emphasize the importance of locally relevant materials in improving learner engagement and understanding (Salacayan et al., 2024; Perez et al., 2025).

Beyond test scores, learner perception data and thematic analysis of open-ended responses suggest that CASL influenced how students understood and reflected on climate change. Learners articulated clearer connections between human activities and climate impacts, recognized the relevance of adaptation strategies, and expressed a growing sense of responsibility toward climate action. Similar outcomes have been reported in climate education studies that integrate socio-environmental contexts and participatory learning strategies (de Rivas et al., 2024; Aclan et al., 2023).

Despite these promising findings, the study has important limitations. The sample was limited to one intact Grade 9 class in a private school, the intervention was short in duration, and no comparison group was included. As such, improvements may also reflect factors such as test familiarity or increased attention during the intervention period. Future research should examine CASL using quasi-experimental designs, include delayed post-tests to assess retention, and explore implementation across diverse school contexts. Nevertheless, the present findings suggest that CASL is a feasible and pedagogically sound approach for supporting climate change education aligned with MELCs and SDG 13.

Limitations

Several limitations of this study should be acknowledged. The intervention was conducted with a single intact class of 22 Grade 9 learners from a private secondary school in Iligan City, Philippines, during Quarter 3 of School Year 2025–2026, which limits the generalizability of the findings. The study employed a one-group pretest–posttest design without a comparison group; therefore, alternative explanations for the observed normalized gain such as test familiarity, teacher or researcher influence, Hawthorne effects, or short-term maturation cannot be fully ruled out. In addition, the two-week duration of the intervention captures only short-term learning outcomes and does not provide evidence of long-term retention or sustained behavioral change. While the thematic analysis offered insights into learners' perceptions and experiences, the qualitative findings are context-specific and may not represent broader student populations or learning environments.

Implications and Future Research

Despite these limitations, the findings suggest that the Climate Action Simulation Lab (CASL) is a promising and feasible instructional approach for supporting climate literacy and climate change adaptation learning in Grade 9 science classrooms. The alignment of CASL with Most Essential Learning Competencies (MELCs) and Sustainable Development Goal 13 demonstrates its potential for integration into regular classroom instruction without disrupting existing curricular structures.

Future research should consider replicating the intervention with larger and more diverse samples, including public schools and multiple sections, to improve external validity. Employing quasi-experimental or experimental designs with comparison groups would strengthen causal inferences regarding the impact of CASL. Delayed post-tests are also recommended to examine retention of climate knowledge and skills over time. Further qualitative investigations could adopt more rigorous analytic procedures, include multiple student excerpts per theme, and explore how learners translate classroom learning into community climate action. Collectively, these directions can contribute to a more robust understanding of how simulation based and contextualized approaches support promising climate change education in the Philippine context.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The findings of this study indicate that the two-week SDG 13–aligned Climate Action Simulation Lab (CASL) was associated with short-term improvements in Grade 9 learners' understanding of climate factors and climate change adaptation. Post-test scores, supported by the Wilcoxon signed-rank test, showed measurable gains in knowledge acquisition and application of climate concepts. Observation data, used only for documentation of learner engagement and not for instructional revision or iterative decision-making, further suggested active learner engagement, collaboration, and critical thinking during CASL activities. In addition, the high validity and reliability of the CASL worksheets confirm that the instruments were appropriate for measuring learning outcomes within this classroom context. While the study demonstrates that a simulation-based, curriculum-aligned approach can support meaningful learning, the results are limited to one class, over a short two-week period, and without a comparison group. Therefore, findings should be interpreted as evidence of promising short-term gains rather than definitive proof of effectiveness.

Recommendations

Based on the study's findings and contextual limitations, the following recommendations are proposed:

Instructional Practice: Teachers are encouraged to integrate simulation-based learning strategies, such as CASL, into science instruction to enhance conceptual understanding and support higher order thinking. Reflective debriefings following each simulation can help learners connect climate concepts to real world Philippine contexts. Performance data from CASL worksheets may guide differentiated support tailored to individual learner needs.

School and Curriculum Planning: School administrators and curriculum planners may consider institutionalizing CASL or similar simulation activities as part of climate education and disaster risk reduction initiatives. Investments in low cost, localized simulation materials and professional development for teachers can facilitate promising inquiry-based and SDG 13 aligned instruction.

Future Research: Further studies are recommended to strengthen the evidence base, including quasi-experimental or comparative designs with larger samples, delayed post-tests to assess retention, and replication in diverse school settings. Expanding CASL to other grade levels or integrating it with other subject areas could provide insights into its broader applicability. Future research could also explore how simulation learning influences students' climate attitudes, community participation, and adaptive capacities, thereby contributing to a more comprehensive understanding of climate education in the Philippine context.

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