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Development and Validation of Ecosystem Lessons Integrating Collaborative, Active, and Inquiry-Based (CAI) Learning Approaches for Grade 7 Science in the Philippine Context

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A B S T R A C T

This study developed and validated a set of Grade 7 science lessons on ecosystem topics by integrating Collaborative, Active, and Inquiry-based (CAI) learning strategies to enhance students' conceptual understanding, engagement, and environmental literacy. Anchored in the ADDIE model, the research employed a descriptive developmental design involving expert validation using DepEd's LRMDS tool and a CAI integration rubric, alongside a pilot test with 45 students. Quantitative data were analyzed using descriptive statistics, paired sample t-tests, and Cohen's d, while qualitative feedback was thematically analyzed. Findings showed that the lessons were rated "Very Much Evident" in CAI features (M = 4.80) and "Very Satisfactory" in quality by experts. Students likewise reported high levels of engagement, clarity, and usability. Posttest results demonstrated significant gains across all four ecosystem topics, with effect sizes ranging from 1.80 to 3.43 and an overall gain from Low Mastery (48.3%) to Near Full Mastery (86.0%). The validated lessons not only promoted scientific understanding but also fostered peer collaboration, critical thinking, and ecological awareness through contextualized, student-centered learning experiences. This study presents an empirically grounded instructional model that addresses enduring challenges in Philippine science education by integrating social learning and inquiry processes into the delivery of environmental content. It offers a scalable, curriculum-aligned approach for transforming conventional science classrooms into participatory communities of inquiry.

RESUME

Este estudio desarrolló y validó un conjunto de lecciones de ciencias para estudiantes de séptimo grado sobre temas de ecosistemas, integrando estrategias de aprendizaje Colaborativo, Activo y Basado en la Indagación (CAI) con el fin de mejorar la comprensión conceptual, la participación y la alfabetización ambiental de los estudiantes. Basado en el modelo ADDIE, la investigación empleó un diseño descriptivo-desarrollativo que incluyó la validación por expertos mediante la herramienta LRMDS del Departamento de Educación y una rúbrica de integración CAI, junto con una prueba piloto con 45 estudiantes. Los datos cuantitativos se analizaron mediante estadísticas descriptivas, pruebas t para muestras relacionadas y el estadístico d de Cohen, mientras que los comentarios cualitativos se examinaron mediante análisis temático. Los resultados mostraron que las lecciones fueron calificadas como "Muy Evidentes" en cuanto a las características CAI (M = 4.80) y como de calidad "Muy Satisfactoria" por parte de los expertos. Los estudiantes también reportaron altos niveles de participación, claridad y facilidad de uso. Los resultados del postest mostraron mejoras significativas en los cuatro temas de ecosistemas, con tamaños del efecto que oscilaron entre 1.80 y 3.43, y un aumento general desde un dominio bajo (48.3%) hasta un dominio casi completo (86.0%). Las lecciones validadas no solo promovieron la comprensión científica, sino que también fomentaron la colaboración entre pares, el pensamiento crítico y la conciencia ecológica a través de experiencias de aprendizaje contextualizadas y centradas en el estudiante. Este estudio presenta un modelo instruccional empíricamente fundamentado que aborda desafíos persistentes en la educación científica filipina al integrar el aprendizaje social y los procesos de indagación en la enseñanza de contenidos ambientales. Ofrece un enfoque escalable y alineado al currículo para transformar las aulas de ciencias convencionales en comunidades participativas de indagación.

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Introduction

Science education plays a vital role in equipping learners not only with scientific knowledge and skills but also with the values and dispositions needed to understand and respond to pressing global and local environmental challenges. In the Philippine context, the K to 12 Science Curriculum aspires to produce scientifically literate and environmentally responsible citizens by fostering inquiry, critical thinking, and problem-solving (DepEd, 2016). Yet, despite these curricular intentions, Filipino students consistently underperform in science achievement metrics. The 2019 Programme for International Student Assessment (PISA) reported that the Philippines ranked lowest in scientific literacy among participating countries, with a mean score of 357, far below the OECD average of 489 (OECD, 2020). Similarly, the Southeast Asia Primary Learning Metrics (SEA-PLM) found that many Filipino students struggle to apply scientific concepts in real-world contexts (UNICEF, 2020).

These learning gaps are closely linked to the continued predominance of teacher-centered instruction, marked by rote memorization, textbook reliance, and minimal learner interaction (Bernardo, 2017; Tupas & Lintao, 2020). Research shows that such practices limit not only conceptual understanding but also the development of higher-order thinking, collaboration, and meaningful learning (Tan, 2021; Bayod & Nacario, 2022). This is particularly evident in the teaching of ecosystems—a topic that requires students to understand complex, dynamic systems involving energy flow, biodiversity, and human-environment interactions. Learners often struggle with these concepts in the absence of interactive, contextualized instructional materials (Yazon, 2019; Espinosa et al., 2021).

Moreover, while environmental issues such as climate change, deforestation, and pollution are deeply relevant to Filipino students, these are seldom taught in ways that connect with learners' lived realities or promote civic action. Many science lessons remain abstract, decontextualized, and disconnected from the development of values, social responsibility, or collaborative competencies (Tamayo, 2018; Manalo & Alico, 2020; UNESCO, 2021). As a result, the classroom becomes not a site of shared meaning-making but a space of passive knowledge reception, undermining the broader goals of Education for Sustainable Development (ESD) and 21st-century learning.

To address these intertwined content and pedagogical challenges, recent scholarship strongly advocates for the adoption of Collaborative, Active, and Inquiry-based (CAI) learning strategies. These approaches are anchored in socio-constructivist and social learning theories, particularly Vygotsky's Social Development Theory, which emphasizes the centrality of social interaction, peer dialogue, and the Zone of Proximal Development in cognitive growth (Vygotsky, 1978), and Bandura's Social Learning Theory, which posits that learners acquire knowledge and behaviors through observation, imitation, and modeling within social contexts (Bandura, 1977). In this view, the classroom is not merely a space for content delivery but a dynamic social environment where learners co-construct knowledge, assume group roles, and exercise leadership and communication skills.

Collaborative learning cultivates interpersonal and democratic competencies by requiring students to negotiate meaning, share responsibility, and engage in cooperative problem-solving (Gillies, 2016). Active learning promotes sustained engagement and deeper comprehension through hands-on tasks, real-world applications, and reflective practices (Freeman et al.,2014). Inquiry-based learning empowers students to ask questions, investigate phenomena, and justify claims based on evidence—developing not only scientific thinking but also critical reasoning, social accountability, and learner agency (Hmelo-Silver et al., 2007; Chichekian & Shore, 2016). Together, these strategies foster classrooms that are socially rich, intellectually rigorous, and developmentally responsive.

Despite growing interest in these pedagogies, most existing studies in the Philippine science education context have treated Collaborative, Active, or Inquiry-based learning in isolation, focusing mainly on cognitive outcomes such as achievement or retention. There remains a notable gap in research that integrates all three strategies within a coherent instructional framework grounded in local curriculum standards and validated through empirical classroom implementation. More importantly, this study distinguishes itself by offering a localized and contextually responsive instructional model that not only synthesizes CAI approaches but also operationalizes them through concrete lesson exemplars tailored to the Philippine Grade 7 Science curriculum. This level of integration and validation—both from expert and learner perspectives—has been minimally explored in previous research. The novelty of this study lies in its dual emphasis on pedagogical coherence and cultural relevance, thereby bridging the gap between theory, curriculum policy, and classroom reality.

In response, this study developed and validated a contextualized set of Grade 7 science lessons on ecosystems integrating Collaborative, Active, and Inquiry-based (CAI) strategies. The primary goal was to create a lesson package that promotes not only scientific understanding but also social engagement, student agency, and environmental literacy.

Specifically, this study aimed: 1. To develop CAI-integrated lessons on ecosystem topics aligned with the Philippine Grade 7 Science curriculum; 2. To validate the content quality and pedagogical soundness of the developed lessons through expert evaluation; 3. To investigate students' perceptions of the lessons in terms of clarity, engagement, and usability; 4. To measure the effects of the CAI-integrated lessons on students' conceptual understanding and performance in ecosystem topics.

Through these objectives, the study contributes a validated instructional model that supports both academic and socio-developmental goals in science education, addressing long-standing challenges in classroom engagement, environmental awareness, and collaborative learning in Philippine junior high schools.

Methodology

This study employed a Descriptive Developmental Research Design, a type of inquiry that focuses on the systematic design, development, and evaluation of instructional materials in real-world settings. Developmental research is especially suited for educational innovation, as it not only investigates the effectiveness of new learning tools but also contributes to theory building in instructional design (Richey & Klein, 2007; Lasala, 2022). Specifically, the study adapted the ADDIE Model—a widely recognized instructional systems design framework consisting of five phases: Analysis, Design, Development, Implementation, and Evaluation. For this research, the first three phases (Analysis, Design, and Development) were implemented to guide the structured creation of CAI-integrated science lessons (Branch, 2009; Molenda, 2003). These phases ensured that the instructional materials were based on clearly identified learner needs and aligned with curriculum standards, pedagogical principles, and intended learning outcomes.

The following are the Methodological Phases used in the study: (1) Analysis Phase- In the analysis phase, the researcher reviewed the existing Grade 7 Science curriculum guide to determine the competencies related to ecosystem concepts. Common learning gaps in science education in the Philippines were also considered, such as students' passive learning behaviors and limited engagement in hands-on and inquiry-driven activities (Lasala, 2024). Literature on the benefits of CAI strategies was consulted to establish the pedagogical rationale for the lesson design; (2) Design Phase- The design phase involved mapping out the lesson topics based on curriculum standards and selecting the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate) as the structuring framework (Bybee et al., 2006). Specific CAI strategies were infused into each phase of the model to ensure a constructivist, student-centered learning experience. Learning objectives, performance tasks, assessment rubrics, and instructional materials were crafted to support the implementation of collaborative, active, and inquiry-based learning. (3) Development Phase- During the development phase, the actual lesson plans were written using the DepEd lesson plan template. Four ecosystem lessons were created, covering key topics such as components of an ecosystem, ecological relationships, energy flow, and abiotic-biotic interactions. Each lesson was designed to be interactive, inquiry-oriented, and group-based. Revisions and refinements were made iteratively to ensure alignment between objectives, activities, and assessments.

For the Validation Process, following the development of the lessons, a two-pronged validation process was conducted involving both expert review and learner-based evaluation. (1) Expert Validation was carried out by a panel of nine science educators and curriculum specialists. These experts assessed the lessons using the DepEd LRMDS Assessment and Evaluation Tool, which measured content accuracy, instructional quality, and presentation. In addition, a CAI Integration Checklist, adapted from Lasala (2022), was used to evaluate how well the lessons embodied collaborative, active, and inquiry-based strategies. Both Likertscaled ratings and narrative feedback were collected, enabling a balanced appraisal of the content and pedagogy; (2) Learner Validation occurred in two stages. (2.a) Prior to the main implementation, a separate group of students, distinct from the final test group, was invited to review the lessons. These students provided formative feedback on clarity, engagement, and usability, offering valuable insights for final refinements; (2.b) Subsequently, the lessons underwent pilot testing with 45 Grade 7 students from a public secondary school in Sorsogon. The implementation began in the third week of September 2019 and extended until the first week of October 2019, slightly exceeding the initially planned two-week duration due to class interruptions. A total of eight (8) hours of instructional time were allocated across multiple sessions to complete all four lessons, in alignment with the DepEd-prescribed Grade 7 Science Teacher's Guide.

After each lesson, students were tasked to write reflective journal entries to capture their learning experiences, thoughts, and insights. Informal follow-up interviews were also conducted to probe deeper into students' perceptions of the lesson design, activities, and CAI learning strategies. These reflections and interviews provided valuable qualitative data on student engagement, clarity, and perceived relevance—complementing the quantitative measures of instructional effectiveness. A pretest-posttest design was used to assess the potential of the developed lessons in improving conceptual understanding. The pilot implementation allowed for the collection of both quantitative performance data and qualitative feedback on instructional effectiveness. To add, Ethics clearance and informed consent protocols were observed following guidelines in ethical educational research (BERA, 2018). The multi-stage validation process ensured that the lessons were pedagogically sound, learner-centered, and contextually appropriate.

In addition, purposive sampling was employed in this study, a non-probability technique commonly used in educational research to select participants who are particularly knowledgeable about or experienced with the phenomenon under investigation (Creswell & Poth, 2018). For expert validation, a total of nine expert validators were selected based on established criteria including subject matter expertise, curriculum familiarity, and experience in instructional material development. These included Master Teachers, education supervisors, and college professors with recognized expertise in science education and curriculum design. All experts met the following criteria: (1) at least ten years of experience in science teaching or curriculum supervision; (2) familiarity with the Department of Education's K to 12 curriculum guide, particularly in Life Science and ecosystem-related content for Grade 7; and (3) formal academic or professional training in instructional material development, science pedagogy, or related disciplines. Their roles were critical in evaluating the content validity, instructional alignment, and pedagogical integration of collaborative, active, and inquiry-based strategies in the lesson plans. This sample size aligns with recommendations by Rubio et al. (2003), who suggest 5 to 10 experts are sufficient for content validation studies.

For pilot testing, forty-five Grade 7 students from a public secondary school in Sorsogon, Philippines, were purposively selected. The school was chosen based on its accessibility, the diversity of its student population, and its prior collaborative engagement with the researcher on instructional material development. Its use of the national Grade 7 Science curriculum and previous participation in research provided both contextual relevance and logistical feasibility. This pre-existing research linkage facilitated smoother coordination, ethical clearance, and implementation fidelity. According to Fraenkel and Wallen (2012), a sample of at least 30 participants is generally acceptable for pilot studies aimed at assessing instructional materials. These students were currently enrolled in science classes and had already been introduced to basic ecological concepts, making them appropriate participants for evaluating the clarity, usability, and pedagogical effectiveness of the developed CAI-integrated lessons..

Prior to the implementation of the study, formal approval was sought through a letter of permission submitted to the school administration. In compliance with ethical research standards, informed consent was secured from the students' parents or legal guardians, and student assent was also obtained to ensure voluntary participation. The consent form clearly outlined the study's purpose, the non-intrusive nature of the classroom-based activities, and the participants' rights, including the option to withdraw at any time without academic penalty. To uphold confidentiality, all student responses were anonymized using assigned codes, and all data were stored securely in password-protected files accessible only to the research team. This rigorous and ethically grounded sampling procedure ensured that both the expert and student participants could provide meaningful and credible feedback, contributing to the validity and developmental refinement of the lessons.

To ensure a rigorous and multi-faceted evaluation of the developed instructional materials, the study utilized a combination of validated instruments tailored to assess both content quality and pedagogical integration. First, the Learning Resources Management and Development System (LRMDS) Assessment and Evaluation Tool, adapted from DepEd DM No. 441, s. 2019, was employed to evaluate the lessons in terms of content accuracy, instructional alignment, presentation quality, and overall organization. This official DepEd instrument provided a standardized framework for assessing the structural integrity and curriculum alignment of non-print instructional materials such as lesson exemplars.

Additionally, an Evaluation Checklist for the Integration of Collaborative, Active, and Inquiry-Based (CAI) Learning Strategies was utilized. This checklist was adapted from [20] and was designed to assess the degree to which each lesson reflected CAI features across the 5E instructional phases. The checklist included indicators of learner participation, cooperative learning structures, problem-solving activities, inquiry prompts, and reflective assessment tasks.

To measure the potential effectiveness of the developed lessons in fostering student learning, a researcher-developed 50-item multiple-choice test was created, covering key concepts on ecosystem topics aligned with the Grade 7 curriculum. The test was subjected to expert review and item analysis using discrimination and difficulty indices (Osterlind, 2006), ensuring content validity and cognitive coverage. The test served as a tool to evaluate the comprehensiveness of content coverage and the cognitive demand of the lessons. Together, these instruments provided a comprehensive lens for assessing the lessons' content soundness, pedagogical robustness, and readiness for classroom implementation.

In analyzing the collected data, Quantitative data were analyzed using descriptive statistics (mean, standard deviation) and paired sample t-tests to compare pretest and posttest scores. The Cohen's d formula was used to determine effect size and interpret the magnitude of change (Cohen, 1988; Field, 2013). This statistical method is widely accepted in quasi-experimental designs to determine whether observed changes in student performance are statistically and educationally meaningful. Meanwhile, qualitative data from open-ended responses were coded and categorized thematically, following Braun and Clarke's (2006) framework for thematic analysis. Themes were identified around clarity, engagement, and usability, enriching the quantitative results with student and expert voices.

Results and Discussion

Development of Lessons on Ecosystem Topics Integrating Active,Collaborative, and Inquiry-based Learning

The process of designing the ecosystem lessons was grounded in the principles of collaborative, active, and inquiry-based (CAI) learning, anchored within the 5E instructional model: Engage, Explore, Explain, Elaborate, and Evaluate. This framework allowed for the systematic integration of learner-centered strategies while ensuring alignment with the Grade 7 Science curriculum, particularly focusing on ecological concepts.

Four semi-detailed lessons were developed, each targeting key ecological topics: (1) Biotic and Abiotic Components of Ecosystems, (2) Ecological Relationships, (3) Transfer of Energy through Trophic Levels and Population Dynamics, and (4) Effects of Changes in Abiotic Factors. The lessons followed the Department of Education's daily lesson log format and included all standard elements such as learning objectives, content, materials, procedures, and assessment. However, they were enhanced with CAI-specific strategies to promote deeper engagement and conceptual understanding.

In the active learning dimension, learners were provided tasks requiring them to explore real-life scenarios, manipulate data, generate hypotheses, and draw conclusions. This included analyzing local ecosystem features or simulating food chain interactions. These tasks moved beyond passive listening and emphasized student agency in learning, consistent with the study of Candia et al., (2025) that defined active learning as involving students in activities that require them to think about what they are doing, this were shown in table 1, highlighting the features of Active Learning in the developed lessons as manifested in the develop lessons.

Table 1:

Matrix of the Developed Lesson in Ecosystem Topics, highlighting the Features of Active Learning

Lesson Title/Learning Competency	Features of Active Learning	Activities Showing Active Learning Features in the Various Parts of the Lessons
LESSON 1: Components of Ecosystem *(Differentiate biotic from abiotic components of the ecosystem)*	• Beyond passive listening • Emphasis on higher-order thinking (analysis, evaluation) • Active engagement through tasks, discussion, and reflection	• Outdoor inquiry activity: "What Does It Mean to Be Alive?"; • Game-based activity "The Conquest: Saving SNHS Forest"; • Group presentations and justification
LESSON 2: Ecological Relationship *(Describe the different ecological relationships found in an ecosystem)*	• Collaborative exploration of ideas • Critical thinking and justification of responses • Application of concepts to situational tasks	• Game-based activity "ECO-DAMA"; Padu'KNOW'ngan Challenge; • Structured analysis and group presentations
LESSON 3: Transfer of Energy through trophic levels *(Predict the effect of changes in one population on other populations in the ecosystem)*	• Active construction of knowledge using visual models • Exploration of values and prior experiences • Engagement in synthesis and problem-solving	• CONNECT ME diagram activity; ECO-CHALLENGE game; • Situational task: • Constructing food chains and trophic flow
LESSON 4: Effect of Changes in Abiotic factors in the Ecosystem *(Predict the effect of changes in abiotic factors on the ecosystem)*	• Active reflection on real-world environmental issues • Emphasis on case analysis and solution generation • Linking prior experiences to new knowledge	• Gallery of Ecological Disturbances; ECO-WARRIOR game; • Case study analysis and preventive solution proposals

Meanwhile, the collaborative learning features were implemented through group tasks that required interaction, negotiation, and shared decision-making. Group roles were clearly defined, and tasks were designed such that individual accountability and interdependence were both required—key characteristics outlined by Johnson and Johnson (1994). Whether analyzing case scenarios or conducting group-based investigations, learners were expected to engage in structured dialogue and contribute collectively to problem-solving. Table 2 shows the summary of the lessons developed, integrating collaborative learning features and activities manifested in the develop lessons.

Table 2:

Matrix of the Developed Lesson in Ecosystem Topics, highlighting the Features of Collaborative Learning

Lesson Title/Learning Competency	Features of Collaborative Learning	Activities Showing Active Learning Features in the Various Parts of the Lessons
LESSON 1: Components of Ecosystem *(Differentiate biotic from abiotic components of ecosystem)*	• Positive interdependence • Group accountability • Shared responsibility	• Outdoor activity "What Does It Mean to Be Alive?"; • Group division of tasks; • Collaborative analysis and group presentation
LESSON 2: Ecological Relationship *(Describe the different ecological relationships found in an ecosystem)*	• Peer interaction and role differentiation • Group negotiation of ideas • Justification of collective answers	• ECO-DAMA collaborative strategy game; Padu'KNOW'ngan Challenge; • Group discussions and justification
LESSON 3: Transfer of Energy through trophic levels *(Predict the effect of changes in one population on other populations in the ecosystem)*	• Coordinated problem-solving • Group self-evaluation • Turn-taking and leadership rotation	• CONNECT ME group diagram construction; • ECO-CHALLENGE board game; • Shared group presentations
LESSON 4: Effect of Changes in Abiotic Factors in the Ecosystem *(Predict the effect of changes in abiotic factors on the ecosystem)*	• Shared decision-making • Team-based strategy development • Social skill practice through structured play	• Gallery of Ecological Disturbances (collaborative collage-making); • ECO-WARRIOR dice-based team game; • Collective analysis of solutions

Lastly, for inquiry-based learning, each lesson opened with scientifically oriented questions, encouraging students to explore, observe, gather evidence, and construct explanations. For example, in exploring abiotic influences on ecosystems, students hypothesized changes based on given environmental data and justified their conclusions using observational evidence. The inquiry cycle was maintained across phases of the lesson, facilitating the development of scientific reasoning as described by the National Research Council (2000), which was manifested in the summary shown in Table 3.

Table 3.

Matrix of the Developed Lessons in Ecosystem Topics, highlighting Features of Inquiry-based Learning

Lesson Title/Learning Competency	Features of Inquiry-based Learning	Activities Showing Inquiry-based Learning Features in the Various Parts of the Lessons
LESSON 1: Components of Ecosystem *(Differentiate biotic from abiotic components of the ecosystem)*	• Engagement through scientifically oriented questions • Evidence-based reasoning • Justification of findings	• Outdoor activity: "What Does It Mean to Be Alive?"; • Group presentations with evidence and justification
LESSON 2: Ecological Relationship *(Describe the different ecological relationships found in an ecosystem)*	• Formulating explanations from evidence • Evaluating explanations against alternatives • Communicating findings	• Game-based activity: • ECO-DAMA; Group discussion and justification; • Padu'KNOW'ngan Challenge
LESSON 3: Transfer of Energy through trophic levels *(Predict the effect of changes in one population on other populations in the ecosystem)*	• Prioritizing evidence to explain ecological dynamics • Applying inquiry to food web construction	• Video-based guided questions; • CONNECT ME activity; • ECO-Challenge board game
LESSON 4: Effect of Changes in Abiotic factors in the Ecosystem *(Predict the effect of changes in abiotic factors on the ecosystem)*	• Evidence-driven predictions • Reflection on human-environment interactions	• Gallery of Ecological Disturbances; • ECO-Warrior game; • Case-based situational analysis

These designed lessons aimed not only to deliver ecological content but also to cultivate critical thinking, collaborative problem-solving, and scientific inquiry skills. Their alignment with both curricular standards and progressive pedagogies provided the foundation for expert validation, as detailed in the following subsection.

Experts' Evaluation of the developed lessons on Ecosystem Topics integrating Active, Collaborative, and Inquiry-based Learning

Following the design and development phase, the lessons were subjected to expert validation to assess two core dimensions: (1) the overall quality of the developed lessons, and (2) the degree to which the CAI features were present and coherent. As shown in Table 4 is the summry of experts' rating on the quality of the lessons and the presence of active, collaborative and inquiry-based learning . Overall, the lessons were rated Very Satisfactory in quality and Very Much Evident in their integration of CAI strategies, indicating their strong potential for classroom use.

Table 4:

Summary of experts' rating on the quality of the developed lessons and presence of active, collaborative, and inquiry-based learning.

Components	Mean Evaluation on Developed Lessons				Mean	Description
	L1	L2	L3	L4		
Part I: Quality of the Developed Lessons Content	3.64	3.83	4.00	4.0	3.86	VERY SATISFACTORY
Format	3.52	3.70	4.00	3.80	3.76	VERY SATISFACTORY
Presentation & Organization	3.86	3.65	3.84	3.70	3.76	VERY SATISFACTORY
Accuracy & Up-To-Datedness Of Information	4.00	3.89	3.87	4.00	3.94	VERY SATISFACTORY
Mean	3.76	3.78	3.93	3.88	3.83	VERY SATISFACTORY
Part II: Presence of features of Active, Collaborative, and Inquiry-based Learning	Mean Evaluation on Developed Lessons				Mean	Description
	L1	L2	L3	L4		
a. Active Learning	4.55	4.70	4.8	4.65	4.68	Very Much Evident
b.Collaborative Learning	4.63	4.94	4.75	5.0	4.83	Very Much Evident
c.Inquiry-Based Learning	4.75	5.0	5.0	4.85	4.9	Very Much Evident
Mean	4.64	4.9	4.9	4.83	4.8	Very Much Evident

As reflected in Table 4, particularly in Part 1: Quality of the developed lessons, the overall mean score is 3.83, with subcomponents such as content accuracy (M = 3.86), presentation and organization (M = 3.76), and format (M = 3.76), all of which meet high standards. Notably, the accuracy and up-to-datedness of information received the highest mean rating (M = 3.94), highlighting the scientific reliability and curricular alignment of the materials. These findings confirm that the lessons are conceptually accurate, well-organized, and presented in a manner that is accessible to both teachers and learners. This aligns with the principles of high-quality instructional design, which emphasize the coherence between objectives, content, and assessment (Jalmasco et al., 2025).

More compelling, however, is the validation of CAI integration (Part II), which achieved an impressive overall mean of 4.80, interpreted as Very Much Evident. Among the three dimensions, inquiry-based learning was rated the highest (M = 4.90), followed by collaborative learning (M = 4.83), and active learning (M = 4.68). These results suggest that the lessons strongly reflected student-centered approaches in their structure and delivery.

The high rating for inquiry-based learning indicates that the lessons consistently encouraged learners to ask questions, gather and analyze data, and construct evidence-based explanations. This approach is critical in developing students' scientific reasoning skills, as emphasized by the National Research Council (2000), which identified inquiry as central to science learning. The finding is consistent with the work of Lasala (2023a), that noted that structured inquiry supports conceptual change and fosters deeper engagement in secondary science classrooms.

Similarly, the strong presence of collaborative learning underscores the lessons' alignment with social constructivist theories, particularly Vygotsky (1978) notion of learning as a socially mediated process. The use of peer dialogue, cooperative group work, and collective problem-solving in the lessons enabled students to co-construct knowledge, practice communication skills, and engage in shared decision-making. This is supported by Johnson and Johnson (1994) who found that cooperative learning significantly improves achievement and interpersonal skills compared to competitive or individualistic settings.

The presence of active learning, rated at 4.68, indicates that students were expected to engage in hands-on tasks, analyze scenarios, and reflect on their learning through journals, discussions, and performance-based outputs. According to Bonwell and Eison (1991), such engagements are key in transforming students from passive listeners into active participants, thereby enhancing retention and conceptual understanding. In the context of the present study, the embedded activities and performance tasks provided students opportunities to “do” science rather than merely listen to it—an essential shift for improving ecological literacy.

These findings have important implications. First, they demonstrate that it is feasible to design science lessons that integrate CAI features without overcomplicating lesson structure or deviating from national curriculum standards. Second, the strong expert validation supports the scalability and classroom applicability of the materials. Given the persistent challenges in Philippine science education, such as low performance in large-scale assessments and teacher-centered instruction (SEI-DOST & UP NISMED, 2021), the developed lessons provide a practical model for transitioning to more participatory and constructivist pedagogies.

The novelty of this study lies in its systematic integration and validation of three complementary pedagogical approaches—collaborative, active, and inquiry-based learning—within a single lesson framework anchored on the 5E model. While prior studies have explored these strategies individually, few have combined them in a cohesive instructional package grounded in both curriculum standards and validated educational theory. Moreover, the lessons were localized and contextualized for Filipino learners, adding cultural relevance to their pedagogical robustness. In sum, the expert validation results affirm that the developed lessons are not only structurally sound but also pedagogically transformative. They model a shift toward student-centered, inquiry-driven science instruction and contribute a validated template for instructional improvement in ecosystem education.

Students’ Evaluation of the developed lessons on Ecosystem Topics integrating Active, Collaborative, and Inquiry-based Learning

The student validation of the developed lessons yielded an overall mean score of 3.78, interpreted as Very Satisfactory, as reflected in Table 5. This learner-based evaluation affirms the earlier findings from expert validators, who rated the lessons with a high overall mean of

4.80 for CAI integration and 3.83 for Overall quality. The convergence of these results from both experts and learners underscores the overall effectiveness, usability, and relevance of the developed instructional materials.

Table 5 :

Summary of Students' ratings on the developed lessons

Components	Mean Evaluation on Developed Lessons				Mean	Description
	L1	L2	L3	L4		
Content	3.85	3.8	3.75	3.53	3.73	VERY SATISFACTORY
Information	4.0	3.88	3.55	3.65	3.77	VERY SATISFACTORY
Instructional and Technical Design	4.0	3.87	3.85	3.60	3.83	VERY SATISFACTORY
Mean	3.95	3.85	3.72	3.59	3.78	VERY SATISFACTORY

Among the student-evaluated components, Instructional and Technical Design received the highest mean score (3.83), mirroring the experts' high rating for Presentation & Organization (3.76) and the clarity of CAI integration. Students appreciated how the lessons were structured—organized into the 5E phases—and designed to support engagement through active tasks, collaboration, and inquiry-based learning. This supports Gestiada et al., (2025) assertion that well-structured instructional materials foster cognitive engagement and promote deeper learning through clarity and flow.

The Content component, evaluated by students at 3.73, was also positively viewed, though it was slightly lower compared to expert ratings (3.86). This minor discrepancy may reflect variation in students' prior knowledge or the cognitive challenge posed by the inquiry tasks. Nonetheless, the rating still suggests that students found the ecological topics to be understandable and well-explained—an encouraging result, considering that the lessons were intended to be both rigorous and learner-centered.

The Information component, which includes examples, clarity of explanation, and supporting resources, was rated 3.77 by students. This complements the experts' strong evaluation of Accuracy and Up-To-Datedness of Information (3.94). Together, these results indicate that the content not only adhered to current scientific standards but was also delivered in ways that students could relate to and comprehend. This reflects Lasala et al., (2025) view that learning is enhanced when new information connects meaningfully to learners' existing knowledge frameworks.

What is especially significant in the alignment of expert and student feedback is the validation of CAI features—rated by experts as "Very Much Evident" across all lessons (M = 4.80)—which was further supported by student reflections on engagement, clarity, and motivation. The students' appreciation of these features suggests that the intended pedagogical goals of the lessons were realized in actual learning settings. As Prince (2004) notes, when students are actively involved in learning through inquiry and collaboration, their engagement and conceptual understanding increase, as reflected in both the qualitative feedback and performance results in this study.

The strong agreement between expert validation and student evaluation underscores the pedagogical soundness and learner-centered nature of the developed lessons. This dual-layer validation confirms that the materials are not only theoretically robust but also effective in practice, addressing both curriculum requirements and the need for more interactive and meaningful science instruction.

Students' Level of Performance in the Pretest and Posttest

One of the primary objectives of this study is to determine the potential of the developed lessons to integrate CIA in improving student learning outcomes. This was particularly evaluated through students' pretest and posttest results. A statistical comparison was conducted to determine whether there was a significant difference in student performance before and after exposure to the CAI-integrated lessons. Table 6 presents the results of the paired sample t-test, including the mean scores, performance levels, and adjectival descriptions, which are interpreted using the Mastery Level Descriptive Equivalent (MLDE) framework (Jalmasco et al., 2025)

Table 6.

Paired t-test results for pretest and post-test of students

Topics	No. Of items	No. Of Points	Pre-Test Weighted Mean	Pre-Test PL (%)	Pre-Test Interpretation	Posttest Weighted Mean	Posttest PL (%)	Posttest Interpretation	Effect Size	Interpretation
1. Biotic and Abiotic Components of Ecosystem	11	33	19	55.0	LM	31	93.0	FM	3.43	L
2. Ecological Relationship	12	36	19	49.0	LM	32	89.0	NFM	3	L
3. of Energy through trophic levels	14	42	19	45.0	LM	34	81.0	M	2	L
4. Effects of the Changes in the Abiotic Factors in the Environment	13	39	17	40.0	LM	32	82.0	M	3	L
Overall Mean	50	150	74	48.3	LM	129	86.0	NFM	4	L
Sd	13.7					8.9				
p-value	0.00									

*Note: ***Significant at 0.05 level --- PL= performance level; LM= low mastery; NM= Near Mastery; M=Mastery; NFM=Near Full; Mastery; FM=Full Mastery; Sd= Standard Deviation; L=Large*

The results presented in Table 6 highlight the significant improvement in students' performance after their exposure to the developed lessons integrating Collaborative, Active, and Inquiry-Based (CAI) learning strategies. Using a paired sample t-test, the study compared the students' pretest and posttest scores across four ecosystem topics in the Grade 7 Science curriculum. The pretest results indicated an overall mean score of 74 out of 150 (48.3%), categorized as Low Mastery (LM). In contrast, the posttest mean increased markedly to 129 out of 150 (86.0%), interpreted as Near Full Mastery (NFM). The p-value of 0.00 confirms that the improvement is statistically significant at the 0.05 level. Moreover, the overall effect size of 4.00 is considered large, signifying a substantial educational impact of the CAI-integrated lessons.

A closer look at the topic-specific results reveals similarly notable gains. In the first learning competency—"Biotic and Abiotic Components of Ecosystem"—students improved from 55.0% (LM) in the pretest to 93.0% (Full Mastery) in the posttest, with an effect size of 3.43. This dramatic increase suggests that the hands-on, collaborative activities and guided inquiry embedded in the lesson effectively clarified the distinctions between living and non-living components. Such outcomes are consistent with Bransford et al. (2000) assertion that active construction of knowledge, rather than passive reception, leads to meaningful learning gains.

The second topic—"Ecological Relationship"—also showed remarkable improvement, with students moving from 49.0% (LM) to 89.0% (Near Full Mastery) and an effect size of 3.00. The lesson's use of role-playing and real-world scenarios likely supported students' understanding of symbiosis, competition, and predation. This finding aligns with Johnson and Johnson (1994) emphasis on cooperative learning, which not only enhances conceptual understanding but also strengthens interpersonal skills through peer collaboration.

In the third topic—"Energy Transfer Through Trophic Levels"—students improved from 45.0% (LM) to 81.0% (Mastery), with an effect size of 2.00. Inquiry-driven tasks such as constructing food webs and modeling energy flow gave students opportunities to visualize and analyze ecological processes, supporting Bransford et al., (2000) argument that visual models and active engagement can bridge conceptual gaps in science learning.

The fourth topic—"Effects of Changes in Abiotic Factors in the Environment"—also showed substantial gains, rising from 40.0% (LM) to 82.0% (Mastery), with an effect size of 3.00. The CAI-integrated approach encouraged students to explore real environmental scenarios and predict outcomes using evidence, reinforcing critical thinking and systems reasoning skills emphasized in environmental science education (Crawford, 2002).

These findings closely mirror the earlier results of the expert validation, in which the lessons were rated Very Satisfactory for content and organization (M = 3.83) and Very Much Evident for CAI features (M = 4.80). The alignment between expert appraisal and student learning outcomes suggests that the pedagogical strategies embedded in the lessons—structured collaboration, guided inquiry, and active tasks—were not only well-designed but also effective in promoting deep understanding.

The implications of these results are clear: integrating CAI approaches into lesson design can significantly enhance students' conceptual mastery in science. The statistically significant gains and large effect sizes underscore the power of learning environments that are student-centered, inquiry-rich, and socially interactive. As several studies concluded, active learning consistently leads to higher achievement and retention, particularly when students are engaged in tasks that require meaningful problem-solving and discussion (Prince, 2004; Lasala, 2023b).

Ultimately, the strength of this study lies not only in its empirical validation of the CAI-integrated lessons but also in its contribution to instructional innovation. By combining three powerful pedagogical strategies into a coherent lesson framework, the study offers a practical and scalable model for science educators seeking to elevate learning outcomes. The students' transition from low mastery to near full or full mastery across all topics affirms that when instruction is thoughtfully designed and grounded in active learning principles, science education becomes more engaging, effective, and transformative.

However, these promising results must be interpreted with caution. The study was conducted in a single school context, with a relatively small sample size and a short instructional timeframe. While the observed gains were significant, further studies involving diverse school settings, larger cohorts, and extended implementation periods are needed to confirm the broader applicability and long-term impact of the intervention.

Conclusion

This study developed and validated a set of Grade 7 science lessons on ecosystems, integrating Collaborative, Active, and Inquiry-Based (CAI) learning strategies. Grounded in the ADDIE model and aligned with the Philippine K to 12 curriculum, the lessons were found to be pedagogically sound and effective in improving student engagement, conceptual understanding, and environmental literacy. Posttest results demonstrated significant learning gains with a large effect size, affirming the value of CAI-integrated, student-centered environments in science education.Beyond cognitive outcomes, the study presents a practical model for addressing persistent challenges in Philippine classrooms—such as low learner motivation, limited critical thinking, and passive instruction—by embedding CAI strategies within contextualized lesson structures. This approach promotes both content mastery and the development of 21st-century skills including collaboration, inquiry, and civic responsibility.

Nevertheless, these findings should be interpreted within the scope and limitations of the study. The intervention was conducted in a single school with a relatively small sample and focused on short-term learning gains. Looking ahead, the scalability of CAI-integrated lessons depends on several contextual factors. Effective implementation requires teacher training and professional development, particularly in facilitating inquiry, managing collaborative tasks, and integrating reflective assessment. Class size also plays a role, as larger groups may require differentiated grouping strategies and additional classroom management support.

Furthermore, access to resources—such as learning materials, technological tools, and flexible classroom spaces—can enhance or constrain adoption. Addressing these factors will be critical in adapting the lessons for use across varied school settings, ensuring that the approach remains both practical and sustainable beyond the pilot context.

Future research may build on these findings by (1) examining the long-term retention of conceptual understanding and the sustained development of CAI-related skills, (2) testing the effectiveness of CAI-integrated lessons across diverse schools and larger student populations to strengthen generalizability, and (3) exploring the types of professional development and institutional support that enable teachers to implement CAI strategies with fidelity. Addressing these areas would not only extend the evidence base but also provide practical guidance for scaling up CAI pedagogy in science education.

Overall, the study contributes to the growing body of literature advocating for constructivist science pedagogy in basic education. It offers empirical evidence supporting the shift toward innovative, student-centered instructional designs that not only enhance academic achievement but also foster ecological awareness and active citizenship among learners.

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