

# From Shoreline to Classroom: Development of a Contextualized Mangrove Literacy Learning Kit (MLLK) to Enhance Grade 10 Learners' Conceptual Understanding and Awareness of Mangrove Ecosystem

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DOI: <https://doi.org/10.47772/IJRISS.2026.100600745>

Received: 28 May 2026; Accepted: 03 June 2026; Published: 04 July 2026

## ABSTRACT

A persistent challenge in science education is learners' limited mastery of ecological concepts, particularly in understanding how species diversity supports adaptation and survival in changing environments. To address this gap, the study developed and validated a contextualized Mangrove Literacy Learning Kit (MLLK) for Grade 10 learners, designed to enhance their conceptual understanding and awareness of the mangrove ecosystem. Anchored on the Department of Education's K–12 Science curriculum and the principles of sustainable development, the research addressed the need for localized, inquiry-based instructional materials that connect ecological concepts with learners' lived experiences. The study employed a Research and Development (R&D) design guided by the modified 4D Model (Define + Ideate, Design + Development, Develop + Validation, Disseminate: Acceptability & Perception). A needs assessment survey was conducted among school administrators and science teachers to identify instructional gaps, leading to the creation of the MLLK using authentic ecological data and photographs from Bayug Island, Iligan City, Philippines. The learning kit covers diverse themes ranging from mangrove ecology, biodiversity, and climate change to environmental laws, integrating inquiry-based activities, reflection journals, and a glossary of technical terms. It was validated by five (5) experts for scientific accuracy, pedagogical soundness, readability, and usability. Implementation involved 84 Grade 10 learners, who completed a 30-item pre-test and post-test scored via ZipGrade. Data were analyzed using the Wilcoxon Signed-Rank Test, supported by descriptive statistics, effect size, and normalized gain scores. Learners' awareness was measured through a 12-item questionnaire, while perceptions of both learners and teachers were gathered through structured evaluation instruments. Results revealed a significant improvement in learners' conceptual understanding (Pre-test  $M = 3.89$ ,  $StD = 3.15$ ; Post-test  $M = 25.96$ ,  $StD = 2.69$ ;  $p = .000$ ) and a dramatic increase in awareness of mangrove ecosystems (from Slightly aware,  $M = 2.46/5$ , to Very aware,  $M = 4.92/5$ ). Learners strongly agreed that the MLLK was clear, engaging, and usable (Overall  $M = 4.92/5$ ), while teachers rated it highly in terms of adaptability ( $M = 4.81/5$ ), suitability ( $M = 4.81/5$ ), and usability ( $M = 4.95/5$ ). These findings affirm the MLLK's effectiveness as a localized, student-friendly instructional innovation. The study contributes to environmental, social, and economic sustainability by fostering ecological literacy, promoting community resilience, and integrating cultural relevance into science education. It aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land). By bridging scientific knowledge with local ecological realities, the

MLLK demonstrates how contextualized instructional materials can empower learners as active stewards of the environment, thereby advancing both educational quality and sustainable development.

**Keywords:** Mangrove Literacy; Contextualized Instruction; Eco-literacy; Biodiversity Education; Environmental Stewardship; Climate Resilience

## INTRODUCTION

Science education in the Philippines continues to face persistent challenges, as evidenced by the 2022 Programme for International Student Assessment (PISA), where Filipino learners obtained a science score of 356—substantially below the OECD average of 485. This performance highlights enduring difficulties in scientific literacy and conceptual understanding, particularly in Biology topics such as ecosystems and biodiversity. Learners often struggle with abstract ecological concepts, leading to misconceptions and fragmented knowledge that hinder meaningful learning. In response, contextualized instruction has been recognized as an effective strategy to improve conceptual understanding by linking scientific content to familiar local situations. Previous studies, such as those conducted by Montero and Geducos (2022) and Guiritan et al. (2023), demonstrated that localized learning packets significantly enhanced learners' mastery of least-understood competencies.

Recent international research further affirms the effectiveness of contextualized and place-based STEM interventions in advancing eco-literacy and biodiversity education. Ardoin, Bowers, and Gaillard (2020) showed that environmental education fosters pro-environmental behaviors and strengthens community conservation capacity. Braun, McLaren, and Swanberg (2022) emphasized the role of inquiry-based eco-literacy in enhancing decision-making for sustainability, while Wu, Wan, and Yu (2023) highlighted how environmental education motivates green consumption and cleaner production practices. In the Philippine context, Domato et al. (2024) validated Contextualized Learning Activity Packets (CLAPs) in biodiversity as “very satisfactory” instructional resources, and Perez et al. (2025) confirmed the effectiveness of contextualized learning materials aligned with the Sustainable Development Goals (SDGs). Collectively, these studies underscore the global and local relevance of contextualized instructional materials, situating the Mangrove Literacy Learning Kit (MLLK) within a broader framework of eco-literacy and sustainability education.

Within environmental education, mangrove ecosystems provide an authentic and meaningful context for science instruction due to their ecological importance in biodiversity, shoreline protection, fisheries productivity, and climate resilience. Despite this, mangrove concepts receive limited emphasis in the Grade 10 Science curriculum, which tends to treat them only as examples within broader biodiversity topics. This lack of focused instructional materials contributes to learners' shallow understanding of mangrove ecology and restricts opportunities for place-based learning. While contextualized instructional resources have been developed for other ecological topics, no validated, curriculum-aligned, and locally contextualized instructional material has yet been designed specifically for mangrove ecosystems. This absence of validated mangrove-specific instructional materials limits learners' opportunities to connect abstract ecological concepts with authentic, place-based experiences. The present study addresses this gap by developing and validating the Mangrove Literacy Learning Kit (MLLK), a localized instructional innovation that integrates ecological data from Bayug Island, Iligan City, Philippines, promotes eco-literacy, and fosters environmental stewardship among learners. Building upon the researcher's prior undergraduate thesis, *Assessment of the Mangrove Ecosystem: Basis for Instructional Material* (Cortes, Esmail, & Jaucola, 2024), this study seeks to develop and evaluate a Contextualized Mangrove Literacy Learning Kit (MLLK) aligned with Grade 10 Science Most Essential Learning Competencies (MELCs). The general objective of this study was to develop a contextualized Mangrove Literacy Learning Kit (MLLK). Specifically, the following objectives were aimed; (1) Assess the instructional needs of the principal/coordinators and science teachers through a needs assessment survey., (2) Develop contextualized Mangrove Literacy Learning Kit (MLLK), (3) Validate the developed contextualized Mangrove Literacy Learning Kit (MLLK), (4) Determine if there is a significant difference in the learners' conceptual understanding of the mangrove ecosystem before and after the utilization of the Mangrove Literacy Learning Kit (MLLK), (5) Measure the improvement in Grade 10 learners' awareness of the ecological, socio-economic, and cultural importance of mangroves before and after exposure to the MLLK. (6) Evaluate the perception of grade 10 learners and science teachers of the developed Mangrove Literacy Learning Kit (MLLK).

## METHODS

This study employed a convergent parallel mixed-methods design within a Research and Development (R&D) framework, anchored on a modified 4D Model (Define + Ideate, Design + Development, Develop + Validation, Disseminate: Acceptability & Perception). Quantitative data (means, standard deviations, frequency distributions, readability scores, and involvement indices) were collected simultaneously with qualitative data (needs assessment responses analyzed through Braun & Clarke's reflexive Thematic Analysis). Both strands were analyzed independently and then integrated during interpretation to provide a comprehensive understanding of instructional needs and to validate the Mangrove Literacy Learning Kit (MLLK). This design allowed numerical evidence of acceptability and usability to be triangulated with thematic insights from administrators and teachers, thereby strengthening the validity of the findings.

The modification of Thiagarajan, Semmel, and Semmel's (1974) 4D model into a contextualized framework reflects the dynamic and iterative nature of instructional material development. By integrating Ideation, Validation, and Perception Assessment, the model preserved systematic rigor while expanding its applicability to localized and learner-centered contexts.

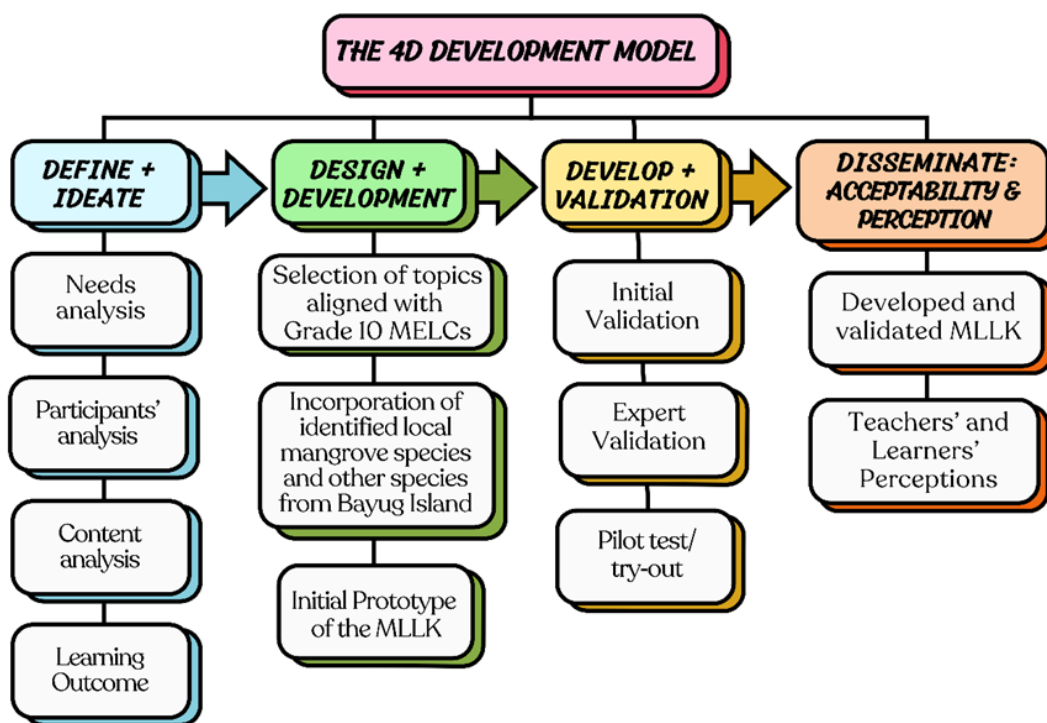


Figure 1. Steps in the Development of Contextualized Mangrove Literacy Learning Kit

The traditional 4D model (Define, Design, Develop, Disseminate) was modified into a contextualized framework to better align with the objectives and actual processes undertaken in this research. Additional components such as Ideation, Validation, Acceptability, and Perceptions were integrated to highlight the creative planning, expert evaluation, and learner feedback that shaped the development of the MLLK. This modification underscores the iterative and participatory nature of the study, ensuring that the instructional material was not only pedagogically sound but also responsive to the ecological context and learner needs.

The first phase, Define and Ideate served as the foundation of the study, focusing on the identification of instructional gaps and the contextualization of content for the Mangrove Literacy Learning Kit (MLLK). A needs assessment was conducted with three (3) school administrators and four (4) science teachers to determine the specific requirements of science instruction, particularly in teaching ecosystem and biodiversity concepts. This survey provided baseline data to establish the necessity of localized instructional materials and to guide the development of the MLLK. The Ideation process complemented the needs assessment by generating creative strategies for embedding ecological awareness and decision-making into Grade 10 lessons. Content ideation focused on aligning with the Most Essential Learning Competencies (MELCs) while incorporating local mangrove species and ecological challenges specific to Bayug Island, Iligan City, Philippines. This ensured that

the MLLK would not only meet curriculum requirements but also raise learners' awareness of the importance of mangrove conservation, ecosystem management, and sustainable decision-making.

The second phase, Design and Development, focused on constructing a detailed plan for the contextualized Mangrove Literacy Learning Kit (MLLK). This step involved aligning the content of the topic Ecosystem and Biodiversity with the identified instructional needs and educational standards. This phase end in the initial draft prototype of contextualized Mangrove Literacy Learning Kit (MLLK) by embedding localized ecological evidence into instructional content, the MLLK not only validated its scientific accuracy but also strengthened its role as a contextualized, learner-centered resource for promoting conservation literacy.

The third phase, the initial prototype of the Mangrove Literacy Learning Kit (MLLK) underwent a series of validation processes to ensure accuracy, readability, usability, and pedagogical soundness. Validation was conducted through face validity, expert validation, and formative evaluation (Fry Readability Test and Romey's Student Involvement Index), with each stage providing feedback that guided refinement. The revised kit was then subjected to a pilot test/tryout with learners to further assess its effectiveness.

In the final phase, Disseminate: Acceptability and Perception, the developed MLLK was implemented to measure the conceptual understanding and mangrove awareness of Grade 10 learners before and after its utilization. Additionally, the perceptions of science teachers and learners regarding adaptability, suitability, and usability were evaluated, providing evidence of the kit's acceptability and relevance for classroom integration.

## Data Analysis

A combination of quantitative and qualitative tools was employed to analyze the data collected throughout the development, implementation, and evaluation of the MLLK:

**Mean ( $\bar{x}$ ):** Used to analyze ratings from learners' and teachers' perceptions, determining the overall acceptability of the MLLK.

**Standard Deviation (SD):** Applied to measure the extent of data dispersion relative to the mean, providing insight into the consistency of responses.

**Frequency and Percentage:** Utilized to capture the distribution of responses and highlight common patterns across participants.

**Thematic Analysis:** Following Braun and Clarke (2021), qualitative data from the needs assessment were systematically coded, categorized, and interpreted to identify recurring themes. Responses from administrators and teachers were analyzed through their utterances, questions, and mentions, which were clustered into meaningful categories. This rigorous process highlighted instructional gaps, contextual priorities, and opportunities for embedding localized ecological content into the MLLK.

## RESULT

### Define and Idiate

The first phase, Define and Ideate, established the foundation of the study by identifying instructional gaps and contextualizing content for the Mangrove Literacy Learning Kit (MLLK). The needs assessment provided baseline data confirming the necessity of localized instructional materials to address learners' difficulties with abstract ecological concepts. School administrators emphasized the importance of bridging curriculum standards with local realities, while science teachers highlighted the challenge of teaching biodiversity without concrete, place-based examples. These findings underscored the need for instructional innovation that integrates mangrove ecosystems as a central theme.

The Ideation process complemented the needs assessment by generating strategies for embedding ecological awareness and decision-making into Grade 10 lessons. Content development was aligned with the Most Essential Learning Competencies (MELCs) while incorporating local mangrove species and ecological issues specific to

Bayug Island, Iligan City, Philippines. This ensured that the MLLK would not only meet curriculum requirements but also cultivate awareness of mangrove conservation, ecosystem management, and sustainable practices among learners.

### Summary of the Need Assessment (Administrators/Principals and Science Teachers)

The needs assessment questionnaires were administered to three (3) administrators/principals and five (4) Science teachers. They all voluntarily participated in the study and were presented first with an approval letter from the DepEd— Division of Iligan City and the school principal. Safety and health protocols were observed and their respective responses were treated with utmost confidentiality. The consolidated findings revealed a shared recognition of the critical role of environmental education in fostering ecological literacy, values, and stewardship. Administrators stressed the motivational role of contextualized materials, emphasizing that the MLLK could bridge “knowing” with “valuing”. While science teachers emphasized the need for interactive, inquiry-based approaches to make ecological concepts tangible and relatable. Both groups identified persistent challenges, including limited resources, lack of contextualized materials, and insufficient integration of experiential activities with theoretical instruction. These perspectives converge on the necessity of the Mangrove Literacy Learning Kit (MLLK) as an instructional innovation that can bridge theory with practice, global science with local context, and knowledge with values.

The implication of these findings is that the Mangrove Literacy Learning Kit (MLLK) can serve as a transformative educational tool, equipping learners with foundational ecological knowledge while fostering critical thinking, appreciation, and long-term commitment to conservation. By situating lessons within the mangrove ecosystem of Bayug Island, Philippines, the learning kit provides a localized, activity-based, and visually engaging approach that addresses both administrators’ concerns about motivation and teachers’ challenges in contextualization. This dual endorsement strengthens the rationale for integrating the MLLK into the science curriculum as a means of embedding sustainability education into classroom practice.

### Design and Develop

The second phase, Design and Development focused on constructing a detailed plan for contextualized Mangrove Literacy Learning Kit (MLLK). This step involved the alignment of the content in the topic “Ecosystem & Biodiversity”, with the identified needs and educational standards from Needs Assessments

### Alignment of Topic in MELCs from DepEd

Table 1 presents the quarter, content standards, performance standards, and Most Essential Learning Competencies (MELCs) used in the study. In competency mapping, once the targeted MELCs were identified, the instructional resources were systematically broken down into smaller, manageable subtasks to ensure clarity, alignment, and progressive scaffolding with the curriculum. This process allowed the Mangrove Literacy Learning Kit (MLLK) to be structured into three logically sequenced chapters, each addressing specific competencies while progressively building toward holistic ecological literacy.

Table 1. Selection of Topics in Most Essential Learning Competencies (MELCs) from DepEd

| Quarter | Content Standard                                                            | Performance Standard                                                                        | MELCs                                                                                                                      | Duration | K to 12 CG Code |
|---------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|----------|-----------------|
| 3rd     | 1. The influence of biodiversity on the stability of ecosystems             | Write an essay on the importance of adaptation as a mechanism for the survival of a species | Explain how species diversity increases the probability of adaptation and survival of organisms in changing environments.  | Week 7   | S10LT-IIh-41    |
|         | 2.An ecosystem as being capable of supporting a limited number of organisms |                                                                                             | Differentiate the components of an ecosystem and Explain the relationship between population growth and carrying capacity. | Week 7   | S10LT-IIh-42    |

The design and content of the contextualized Mangrove Literacy Learning Kit (MLLK) were anchored on these MELCs, specifically: Explaining how species diversity increases the probability of adaptation and survival of organisms in changing environments (S10LT-IIh-41). Differentiating biotic and abiotic components of an ecosystem and explaining the relationship between population growth and carrying capacity (S10LT-IIh-42). By aligning the instructional material with these competencies, the MLLK ensured that learners not only met curriculum requirements but also developed deeper ecological literacy. The kit contextualized abstract concepts into localized, activity-based lessons, enabling learners to connect biodiversity and ecosystem principles with the mangrove realities of Bayug Island, Iligan City, Philippines. This alignment guaranteed that the instructional innovation was both curriculum-compliant and contextually relevant, bridging national standards with local ecological knowledge.

### **Incorporation of Identified Mangrove species and other Fauna and Flora**

The contextualization of the Mangrove Literacy Learning Kit (MLLK) was firmly anchored in the researcher's prior ecological study, Assessment of the Mangrove Ecosystem in Bayug Island: Basis for Instructional Material Development, which provided baseline data on the ecological condition of Bayug Island, Iligan City, Philippines. This descriptive study examined biological, physical, and chemical factors, revealing alarming insights: saplings planted in the area were of the wrong species, reflecting a serious lack of ecological knowledge even in community-initiated programs. Misconceptions about mangroves, misplanting practices such as placing saplings on sea beds where they cannot survive, and garbage accumulation that hindered growth were also observed. Primavera (2021) emphasized the importance of science-based protocols for species-site matching in mangrove rehabilitation, warning that misplanting in unsuitable habitats leads to high mortality and ecological imbalance. This resonates with the Bayug Island, Iligan City, Philippines findings and underscores the need for contextualized instructional materials that can correct misconceptions, strengthen ecological literacy, and promote sustainable practices. One of the key recommendations from the prior study was the creation of localized learning resources to address these instructional gaps.

Biological findings highlighted the abundance of three *Rhizophoraceae* species—*Rhizophora apiculata*, *Rhizophora mucronata*, and *Rhizophora stylosa*—alongside diverse flora and fauna such as invertebrates, birds, and fish. This richness of life confirmed that the site sustains multiple trophic levels and was assessed to be in “excellent” ecological condition. The physical findings revealed that air and water temperatures were suitable for mangrove growth across weather conditions, while canopy cover variation provided favorable conditions for seedling germination. However, high TSS levels during rainy weather suggested significant erosion and pollution in the surrounding land, indicating anthropogenic pressures that could affect long-term ecosystem stability. Chemically, the mangrove ecosystem Bayug Island, Iligan City, Philippines exhibited favorable salinity, pH, and BOD levels conducive to mangrove development, though only pH consistently met the Department of Environment and Natural Resources (DENR) Class SC standards. A drop in pH beyond this range could have corrosive effects on mangrove physiology, disrupting nutrient uptake and growth processes.

Pedagogically, these findings were integrated into the MLLK to contextualize lessons with authentic ecological data. For example, the canopy cover results were used to explain why mangrove seedlings require shade from parent trees rather than direct tropical sunlight, linking ecological adaptation to learner inquiry. Similarly, the water quality data provided opportunities for students to critically examine how chemical parameters influence mangrove survival. By embedding localized ecological evidence into instructional content, the MLLK not only validated its scientific accuracy but also strengthened its role as a contextualized, learner-centered resource for promoting conservation eco-literacy.

### **Drafting the Initial Prototype of MLLK**

In competency mapping, once the targeted learning competencies were identified, the instructional resources were systematically broken down into smaller, manageable subtasks to ensure clarity, alignment, and progressive scaffolding with the curriculum. This process allowed the Mangrove Literacy Learning Kit (MLLK) to be structured into three logically sequenced chapters, each addressing specific competencies while progressively building toward holistic ecological literacy.

Table 2. Selection of Topic in Lesson Exemplar from MELCs' K-12 Curriculum DepEd

| Chapter and Topic                                                                                                             | Learning Competencies                                                                                                                  | Description                                                                                                                                                                                                                                                                                                                               |
|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <b>Chapter 1:<br/>Mangrove Trees</b>         | Explain how organisms adapt to specific environments and contribute to ecosystem sustainability.                                       | Delves into the unique biology of mangrove flora. Learners explore how these specialized trees survive in harsh, saline environments, master species identification, and build a foundational respect for the tree's physical resilience. Leans heavily into the Mind (understanding the science of the tree).                            |
|  <b>Chapter 2:<br/>Mangrove Biodiversity</b> | Explain how species diversity increases the probability of adaptation and survival of organisms in changing environments               | Explores the rich web of life sustained by mangroves. This chapter highlights the forest as a bustling sanctuary, teaching learners to see the ecosystem beyond their physical substrate, but as a thriving, interconnected wildlife hub. Bridges the Mind and Heart (connecting with the living creatures).                              |
|  <b>Chapter 3:<br/>Mangrove Ecosystem</b>    | Explain how ecosystems provide services that maintain environmental balance. Suggest ways to minimize human impact on the environment. | Connects the trees and biodiversity to global climate health. Focuses on the ecosystem services of mangroves—like shoreline protection and carbon sequestration—while empowering learners to step into active, hands-on conservation and community advocacy roles. Drives home the Body (taking action, restoration, and global context). |

The table 2 presents the sequence of topics in the Mangrove Literacy Learning Kit (MLLK), which follows a hierarchical “building block” approach. Lessons progress from specific local applications, introducing mangrove trees, to broader ecological concepts. This progression enables learners to first establish foundational knowledge of ecosystems and biodiversity before engaging in deeper understanding of mangrove ecosystems and species, thereby promoting meaningful and contextualized learning. The MLLK was designed as a student-friendly guide with clear instructions and step-by-step activities. It includes interactive exercises, the “4Ws and 1H” (What, Why, When, Where, and How) about mangrove characteristics, discussion forums, and reflection journals to encourage critical thinking. The kit also integrates indigenous knowledge, acknowledging how Filipino ancestors historically used mangroves for shelter, medicine, and fishing practices, and how local communities protected mangrove forests as vital resources—particularly during disasters such as Typhoon Sendong (2011) and Typhoon Basyang (2025). This cultural integration strengthens the relevance of the kit by connecting scientific knowledge with traditional ecological wisdom, ensuring that learners appreciate both the biological and socio-cultural importance of mangroves.

## Develop and Validation

In this phase, the initial prototype of the Mangrove Literacy Learning Kit (MLLK) underwent a systematic series of validation processes to ensure its accuracy, readability, usability, and pedagogical soundness. Validation was conducted through initial/face validation, expert/content validation, and formative evaluation, with each stage providing critical feedback that guided iterative refinement of the kit prior to its pilot testing/try-out.

|   |                           |
|---|---------------------------|
| 1 | Initial/Face Validity     |
| 2 | Expert/Content Validation |
| 3 | Formative Evaluation      |
| 4 | Revision                  |
| 5 | Pilot Test                |

Figure 2. Validation process of Developing Contextualized of MLLK

The figure 2 illustrates the multi-stage validation process of the Mangrove Literacy Learning Kit (MLLK). The iterative cycle of validation and revision ensured that the final prototype was not only curriculum-aligned but also responsive to learners' needs, thereby strengthening its role as a transformative resource for fostering eco-literacy and environmental stewardship.

## Initial Validation

After the initial prototype of Mangrove Literacy Learning Kit (MLLK) was subjected to initial/face validity evaluation by the researcher's adviser and 3 exploration panel members. The review focused on the accuracy of content, the coherence of instructional flow, and the alignment of the material with Grade 10 Science MELCs. Their responses, including comments and suggestions, were carefully considered and applied to improve and enhance the MLLK, ensuring their relevance and effectiveness in the educational system. Also, their feedback provided critical insights that guided the refinement of the MLLK in the subsequent Develop Phase, ensuring that the material was pedagogically sound, contextually relevant, and responsive to the instructional needs identified during the Define Phase.

Table 3. *Summary of the Comments/ Suggestions from the Validators*

| Validator   | Comments/ Suggestions                                                                                                                                                                                                                                                                                                                 |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Validator 1 | The initial prototype of the MLLK should undergo formative evaluation before expert validation to determine its suitability for the target participants and to ensure that it is not verbose.                                                                                                                                         |
| Validator 2 | Please address the minor grammatical errors in the module. Consider changing the title of your learning kit by adding Biodiversity, as it aligns with the Grade 10 MELCs for the third quarter topic, and include Bayug Island, Iligan City, Philippines to make it an authentic and localized Mangrove Literacy Learning Kit (MLLK). |
| Validator 3 | Add more organisms in the introductory mystery section of the MLLK to spark learners' curiosity. You may also consider adding a link for mobile access to enhance usability.                                                                                                                                                          |
| Validator 4 | Add more organisms in the introductory mystery section of the MLLK to spark learners' curiosity. You may also consider adding a link for mobile access to enhance usability.                                                                                                                                                          |

During the initial face validity, the prototype of the MLLK was reviewed by the adviser and four panel members. Their feedback emphasized formative evaluation, grammatical refinement, contextual authenticity, and learner engagement through added organisms and mobile accessibility. These suggestions were systematically integrated into the revised kit, ensuring that it became scientifically accurate, pedagogically sound, and contextually relevant. The process confirmed that face validity was not just a preliminary step but a critical foundation for refinement, bridging expert recommendations with classroom application and preparing the MLLK for formal expert validation.

## Expert Validation

After incorporating the comment and suggestion, revised based on the results of the initial validation. The developed MLLK validated by experts were two (2) environmentalists or mangrove specialists, to check scientific accuracy. Two (2) pedagogy experts: (e.g., a PhD Teacher or Curriculum Specialist) to check if the activities are right for Grade 10 and to ensure accuracy, clarity, and relevance. One (1) Language/Technical Expert: To check the grammar, clarity, and visual layout. The evaluators utilized the evaluation rating sheet and related descriptors for printed materials, which was a Standardized Rubric prescribed by the Department of Education (2015) to determine whether materials are appropriate for use in public schools and guarantee their accuracy. It has several criteria, which include (a) content, (b) format, (c) presentation and organization, and (d) accuracy and up-to-dateness of information.

Table 4. *Expert's Rating on the Developed Contextualized MLLK*

| Factors                                     | Mean        | Description              |
|---------------------------------------------|-------------|--------------------------|
| Content                                     | 3.93        | Very Satisfactory        |
| Format                                      | 3.93        | Very Satisfactory        |
| Presentation and Organization               | 3.92        | Very Satisfactory        |
| Accuracy and Up-to-datedness of Information | 3.87        | Very Satisfactory        |
| Overall Average                             | <b>3.91</b> | <b>Very Satisfactory</b> |

Legend: 1.00-1.75 (not satisfactory); 1.76-2.50 (poor); 2.51-3.25 (satisfactory); 3.26-4.00 (very satisfactory)

Table 4 results show that the contextualized MLLK was rated Very Satisfactory across all dimensions, with an overall mean of 3.91/4. The close clustering of scores (3.87–3.93) demonstrates consistency among evaluators, indicating that the material is reliable and robust in design. This confirms that the kit meets professional standards of accuracy, clarity, and usability, making it appropriate for integration into the Grade 10 Science curriculum. The expert validation further affirms that the MLLK is scientifically accurate, pedagogically sound, and contextually relevant, ensuring that it can serve as a credible instructional material to foster eco-literacy and sustainability among learners.

## Formative Evaluation

After incorporating feedback from face validity and was subjected to formative evaluation using two objective measures: the Fry Readability Test and Romey’s Student Involvement Index (SII). The Fry Test, based on three 100-word samples, yielded a U.S. Grade 9 level which, after adjustment for the Philippine context, corresponded to a Local Grade 7 level. This confirmed that the text corresponds to a Local Grade 7 level, demonstrating that the kit is not verbose and linguistically accessible for Grade 10 learners. This ensures that students can focus on ecological concepts without being hindered by unnecessary language complexity.

Table 5. *Number of Sentences and Syllables Per Hundred Words*

| Page        | No. of Sentences | No. of Syllables |
|-------------|------------------|------------------|
| First page  | 8.8              | 140              |
| Middle page | 8.2              | 145              |
| Last page   | 8.5              | 150              |
| Average     | <b>8.5≈ 9</b>    | <b>145</b>       |

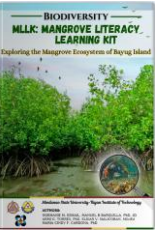
The SII analysis, conducted across three chapters, produced values of 0.81, 1.00, and 0.88, all within the “High Student Involvement” range (0.8–1.5). These results indicate that the MLLK promotes active learner engagement through inquiry-oriented and participatory tasks rather than passive, expository instruction. Together, the readability and involvement findings validate that the MLLK is concise, not verbose, and engaging—making complex ecological topics manageable and meaningful for its intended audience.

## Pilot Test / Tryout

A pilot study was conducted in a separate public high school to evaluate the usability and effectiveness of the Mangrove Literacy Learning Kit (MLLK) and its accompanying assessment instruments in a real classroom environment. This stage was essential in determining whether the instructional material was clear, engaging, and appropriate for Grade 10 learners prior to full implementation. During the try-out, learners were able to follow instructions independently and complete the activities simply by reading the directions provided in the kit. The tasks were accomplished successfully, and both discussions and activities were completed within the allotted science class period. This observation highlighted the practicality of the MLLK and its suitability for integration into regular classroom schedules. One concern noted during the pilot was that several learners encountered unfamiliar scientific terms, which caused confusion in some parts of the module. Since biology is known for its technical terminology, a word bank/ glossary was added at the back of the MLLK to provide definitions of key terms and support learner comprehension. The finalized kit therefore featured improved readability, enhanced activity sequencing, and strengthened ecological content, making it both adaptable and sustainable for classroom use.

Table 6. *Summary of the Evolution of the Mangrove Literacy Learning Kit (MLLK)*

| Version                                                                                         | Content Evolution                                                                                                                                                                                                                                                                                         |
|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Version 1<br> | The initial prototype introduced the basic structure of the kit: title page, objectives, introduction, localized images, and inquiry-based activities. The content was drafted directly from the needs assessment; however, the language remained technical, and some activities lacked clear sequencing. |
| Version 2                                                                                       | Following initial/face validation, content was revised for clarity and readability. Instructions                                                                                                                                                                                                          |

|                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|               | were simplified, activity flow was improved, and alignment with Grade 10 Science MELCs was strengthened. Visuals were adjusted to better reflect the ecological context.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Version 3<br> | Through content/expert validation, biology educators enhanced scientific accuracy and pedagogical soundness. Content was updated to correct minor factual errors, enhance ecological explanations, and integrate higher-order thinking activities.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Version 4<br> | The kit underwent formative evaluation using readability and engagement measures. Content was streamlined to avoid verbosity, sentence structures were shortened, and activities were sequenced to gradually build conceptual understanding. The Student Involvement Index confirmed that contextualized content and localized images encouraged active participation.                                                                                                                                                                                                                                                                                                                                                                         |
| Version 5<br> | During the pilot test/tryout, learners engaged with the kit but struggled with unfamiliar scientific terms. As a result, a glossary/word bank was added at the end of the kit to support comprehension. Content was further refined to ensure accessibility, with improved activity instructions and reinforced ecological concepts. This final version was validated as learner-friendly, reliable, and classroom-ready.                                                                                                                                                                                                                                                                                                                      |
| Version 6<br> | The final prototype incorporated all revisions from previous stages and emerged as a classroom-ready instructional material. It strategically balanced clarity, contextualization, and inquiry-based learning, ensuring that learners could independently navigate activities while engaging deeply with ecological concepts. By embedding localized data, indigenous knowledge, and a glossary of technical terms, the kit became both accessible and culturally relevant, supporting diverse learners and promoting ecological stewardship. This version not only addressed curriculum standards but also embodied best practices in instructional design, making it a sustainable and adaptable model for contextualized science education. |

### Features of the Developed and Enhanced Contextualized MLLK

The finalized Mangrove Literacy Learning Kit (MLLK) consists of the following components: Title Page, Table of Contents, Learning Objectives, Introduction, Learning Activities, Assessment/Evaluation, Word Bank, and References.

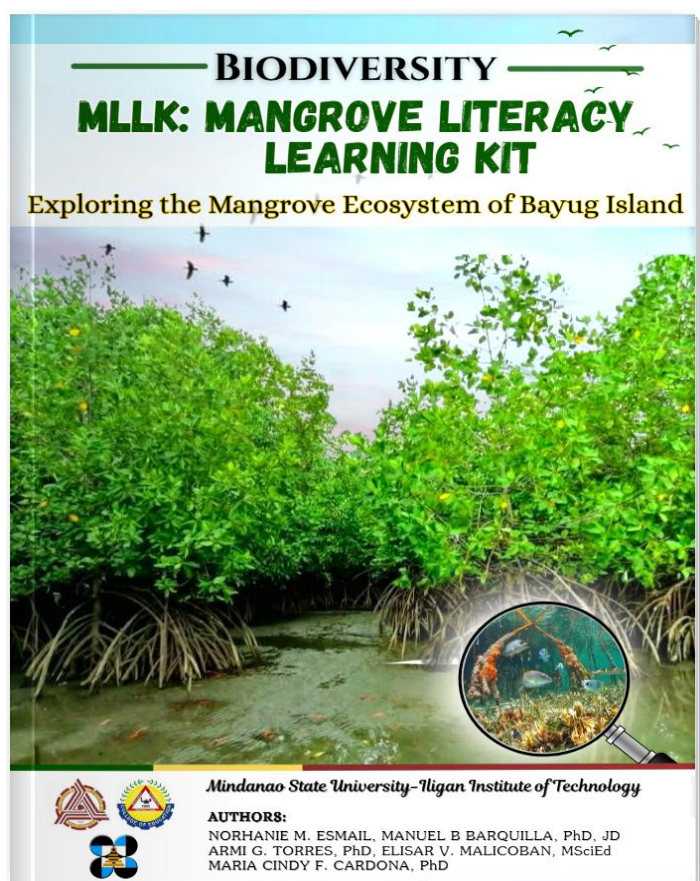


Figure 3. Title Page of the Contextualized Mangrove Literacy Learning Kit (MLLK)

The title page of the Mangrove Literacy Learning Kit (MLLK) features a captured image of a mangrove forest customized by the researcher to highlight species documented in Bayug Island, Iligan City, Philippines. Its design emphasizes the ecological principle that species diversity increases the probability of adaptation and survival in changing environments. Following face and expert validation, no revisions were recommended, affirming the appropriateness of the title page for the finalized MLLK. Beyond aesthetics, the design was anchored on key learning theories that guided the development of the MLLK. Constructivist Learning Theory supports the use of authentic contexts, allowing learners to connect abstract ecological concepts with real mangrove species from Bayug Island, Iligan City, Philippines. Situated Learning Theory emphasizes embedding instruction in local ecological and cultural realities, making the title page a meaningful entry point for contextualized science learning. And Vygotsky's Sociocultural Theory underscores the role of cultural tools and context in scaffolding learning; by integrating localized ecological data and imagery, the MLLK provides learners with culturally relevant supports that enhance comprehension and engagement.

| TABLE OF CONTENT                                          |      |
|-----------------------------------------------------------|------|
| FRONT MATTER                                              | Page |
| About the MLLK & Development Team                         | 2    |
| Copyright and Permissions                                 | 2    |
| Foreword                                                  | 4    |
| Description                                               | 5    |
| Introduction Message                                      | 6    |
| <b>CHAPTER 1: MANGROVE TREES – THE SILENT GUARDIANS</b>   |      |
| 1.1 What is a Mangrove?                                   | 13   |
| 1.2 Global Perspective: Types of Mangroves in the World   | 17   |
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| <b>CHAPTER 2: MANGROVE BIODIVERSITY – THE WEB OF LIFE</b> |      |
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Figure 4. Table of Contents of the Contextualized Mangrove Literacy Learning Kit (MLLK)

The table of contents served as a guide on what are the contents of the module with its corresponding page number. It consisted of the cover page, introductory message, table of contents, and a guide on how to learn from this module. It has different elements, too. In addition, it has corresponding labels in English. These were 1) What I Need to Know or the Introduction/Learning Objectives, (2) What I Know or the Pretest, (3) What's In/ Review (4) What's New/ Activity 1, (5) What Is It/ Discussion of Activity 1, (6) What's More/ Enrichment Activities, (7) What I Have Learned or the Generalization, (8) What I Can Do/Application and (9) Assessment or the Post Assessment.


**Activity 1: What I Know?**

**PRE-TEST**

**Instruction:** Read each question carefully. Select and circle the letter of your answer. Don't worry if some questions seem unfamiliar- this pretest is simply meant to give you a sense of what you already know and what areas might need a bit more focus as we move forward.

1.What is a mangrove?

A. A type of coral reef organism

B. A coastal plant that grows in salty or brackish water

C. A freshwater plant found in rivers

D. A type of seaweed

2.Mangrove trees are commonly found in which environment?

A. Mountain forests

B. Deserts

C. Coastal areas and estuaries

D. Grasslands

3.Which of the following is a common mangrove genus in the Philippines?

A. *Rhizophora*

B. *Avicennia*

Figure 5. Pre-test of Contents of the Contextualized Mangrove Literacy Learning Kit (MLLK)

Before engaging with the module activities, students completed a pre-assessment to establish baseline knowledge. The results were later compared with post-test scores after each chapter, enabling learners to track their progress and growth. This approach, supported by a reliable local study you can cite is Abuloc & Limpot (2026), which examined Filipino students' learning motivation, readiness for blended learning, and self-efficacy. Their findings confirm that structured pre-assessments and motivational strategies significantly enhance attentiveness, confidence, and engagement among learners in the Philippines.

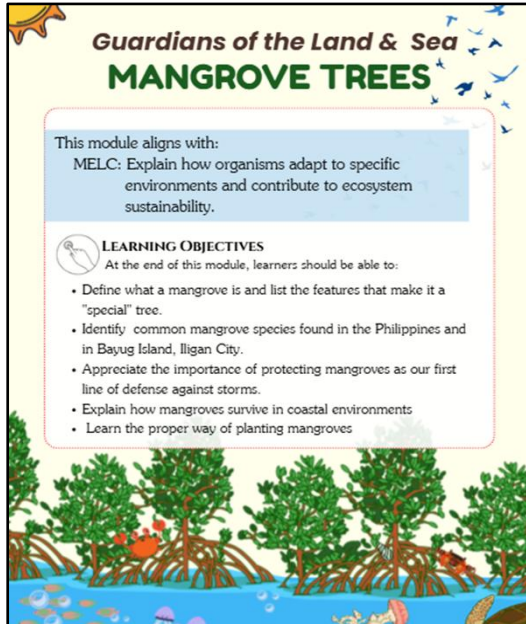


Figure 6. Introduction in each Chapter of Contents of the Contextualized Mangrove Literacy Learning Kit (MLLK)

The introduction provides an overview of each lesson and begins with clearly stated learning objectives that specify what students are expected to achieve after engaging with the MLLK. These objectives ensure alignment with the curriculum and guide learners toward meaningful outcomes. Each chapter presents objectives alongside colorful visuals and carefully selected images related to the topic, helping readers form initial connections, spark curiosity, and encourage active engagement. By combining clear objectives with contextualized imagery, the introduction sets the tone for a purposeful and interactive learning journey.

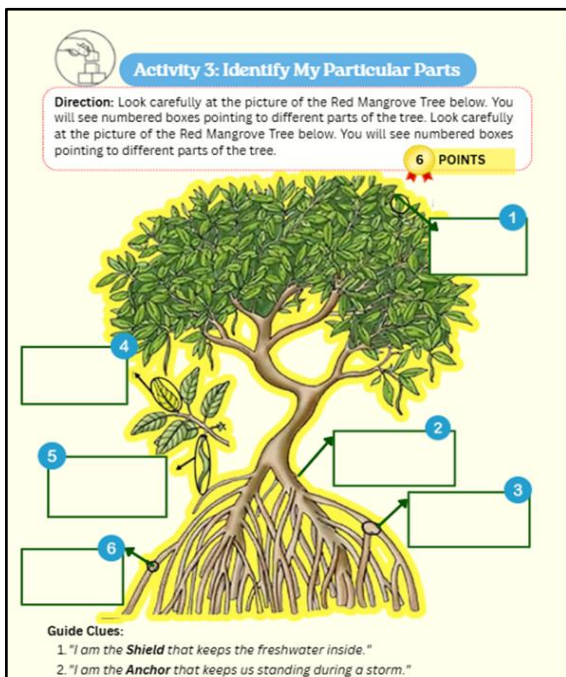


Figure 7. Learning Activities of the Contextualized Mangrove Literacy Learning Kit (MLLK)

Each chapter of the MLLK includes a variety of learning activities designed to deepen understanding while keeping learners engaged. Clear guidelines help readers follow tasks with ease, while colorful and interactive exercises test comprehension of the topics. At the end of every discussion, an activity reinforces key concepts through simple yet thought-provoking tasks, often described by participants as “tricky but thrilling.” This balance of creativity and academic rigor ensures that learners remain motivated, challenged, and actively involved, transforming the Mangrove Literacy Learning Kit into an engaging tool that promotes both critical thinking and enjoyable learning.

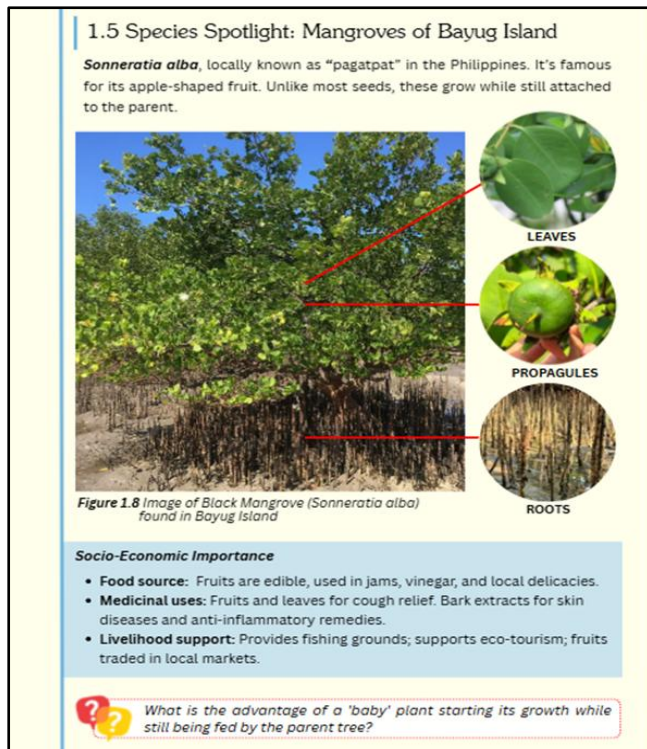


Figure 8. Interactive Discussion Features of the Contextualized MLLK

Authentic and contextualized content, featuring mangrove species and other organisms directly documented in Bayug Island, Iligan City, Philippines. This enables learners to connect the material with real-life experiences—when visiting Bayug Island, Iligan City, Philippines, Iligan City, Philippines for mangrove planting, they can encounter the exact species highlighted in the module, deepening appreciation and relevance. Enriched with icons for trivia, questions, and key points, makes the MLLK interactive and engaging while connecting learners to real mangrove species documented in Bayug Island, Iligan City, Philippines.

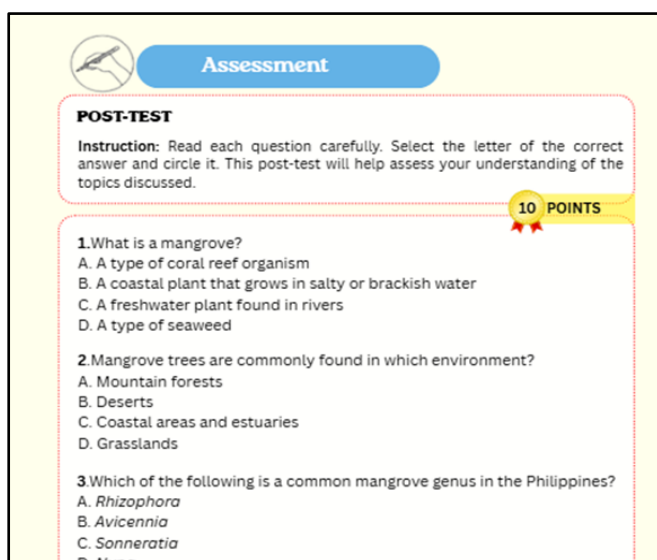


Figure 9. Assessment/Evaluation of the Contextualized Mangrove Literacy Learning Kit (MLLK)

At the end of each chapter, learners completed a post-assessment designed to measure improvement and determine whether the learning objectives had been achieved. The posttest items were identical to those in the pretest, allowing direct comparison of scores to assess knowledge gains. This approach is supported by Hornbuckle (2022), who emphasized that posttests demonstrate whether students have acquired the necessary knowledge and reveal the extent of their improvement. By aligning pretest and posttest items, the evaluation provided clear evidence of the effectiveness of the MLLK in enhancing learners' conceptual understanding.

| The Mangrove Word Bank: A Glossary of Terms |                                                                                                                   |
|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| Term                                        | Definition in the Mangrove World                                                                                  |
| <b>Mesofauna</b>                            | Very tiny animals (smaller than what you can easily see) that live in the soil or leaf litter.                    |
| <b>Niche</b>                                | The specific "job" or role an organism has in its environment (e.g., a crab's job is cleaning the mud).           |
| <b>Nursery</b>                              | A safe place provided by mangrove roots where young fish (fry) can grow up protected from big predators.          |
| <b>Propagule</b>                            | A mangrove "seed" that is already partially grown while still attached to the parent tree.                        |
| <b>Resilient</b>                            | The ability of an ecosystem like Bayug Island to "bounce back" or recover after a storm like Basyang.             |
| <b>Sedimentation</b>                        | The process of soil and sand settling at the bottom of the water, which mangroves help to trap.                   |
| <b>Snorkels</b>                             | A nickname for <i>Pneumatophores</i> —specialized roots that stick up out of the mud to "breathe" air.            |
| <b>Stabilizes</b>                           | To make something firm and steady. Mangrove roots stabilize the shoreline so it doesn't wash away.                |
| <b>Scaffolding</b>                          | The structure of roots that hold the mangrove tree up, looking like "legs" walking on water.                      |
| <b>Tangled Roots</b>                        | The messy, complex web of roots that makes it hard for predators to swim through, protecting small fish.          |
| <b>Viviparous</b>                           | A unique trait where the "seed" (propagule) starts growing while still on the tree, instead of falling off first. |
| <b>Zonation</b>                             | The way different mangrove species grow in specific "belts" or layers depending on how close they are to the sea. |

Figure 10. Word Bank/Glossary of the Contextualized Mangrove Literacy Learning Kit (MLLK)

The developed module includes a word bank that serves as a glossary, enabling learners to easily look up unfamiliar terms and reduce confusion. By providing clear explanations of technical and scientific vocabulary, the glossary builds confidence, supports comprehension, and encourages deeper exploration of the content. This feature transforms the MLLK into a learner-friendly guide, ensuring accessibility while promoting curiosity and engagement. As Litmos (2026) emphasizes, glossaries and word banks are essential for accessible learning, allowing students from diverse backgrounds and language proficiencies to fully engage with instructional materials.

| References                                                                                                                                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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Figure 11. References of the Contextualized Mangrove Literacy Learning Kit (MLLK)

The last part of the developed contextualized MLLK was the references where different sources were presented to acknowledge the other people's work that was used in developing this Mangrove Literacy Learning Kit (MLLK). This section ensures academic integrity by giving credit to the authors and studies whose work contributed to the development of the instructional material.

### Disseminate: Acceptability and Perception

In this phase, the developed and validated Mangrove Literacy Learning Kit (MLLK) was disseminated to the target participants to evaluate its acceptability and gather perceptions regarding its adaptability, suitability, and usability. Having undergone initial/face validation, content/ expert validation, formative evaluation and pilot test/tryout. The MLLK was considered reliable and ready for classroom implementation. Learners and science teachers were then engaged to provide feedback on its features and overall effectiveness.

### Conceptual Understanding of Grade 10 Learners' Towards MLLK

A 30-items pre-test and post-test was given to Grade 10 learners included eighty-four (84) who participated willingly and signed the consent and assent form to assess their conceptual understanding before and after using the contextualized MLLK to identify the level of significance.

Prior to inferential analysis, the data were subjected to a normality test to determine the appropriate statistical procedure. If the data had been normally distributed, a paired sample t-test would have been used. However, since the results indicated that the data were non-normal, the Wilcoxon Signed-Rank Test was employed.

Table 7. Wilcoxon Signed-Rank Test Result on the Pre-test and Post-test Scores (n = 84)

| Variable  | Mean  | StD  | Min | Max | Test Statistic | P-value | Remark      |
|-----------|-------|------|-----|-----|----------------|---------|-------------|
| Pre-test  | 3.89  | 3.15 | 1   | 16  | -7.971         | .000    | Significant |
| Post-test | 25.96 | 2.69 | 16  | 30  |                |         |             |

Legend: Significant at  $\alpha = 0.05$

Table 7 presents the Wilcoxon Signed-Rank Test results comparing the pre-test and post-test scores of the 84 Grade 10 learners who used the Mangrove Literacy Learning Kit (MLLK). The learners' mean pre-test score was 3.89 (SD = 3.15), with scores ranging from 1 to 16, reflecting limited prior knowledge of mangrove ecology. After implementation, the mean post-test score rose sharply to 25.96 (SD = 2.69), with scores ranging from 16 to 30. The test statistic of  $-7.971$  and a p-value of  $.000$  ( $\alpha = 0.05$ ) confirm a statistically significant difference between the pre-test and post-test scores.

The null hypothesis ( $H_0$ ) stating that there is no significant difference between the pre-test and post-test scores was therefore rejected, providing sufficient evidence that the learners' conceptual understanding significantly improved after using the MLLK. The reduction in standard deviation from 3.15 to 2.69 further indicates that learners' performance became more consistent, suggesting that the kit not only raised overall achievement but also minimized disparities in understanding across the group.

This result demonstrates that the MLLK successfully bridged the instructional gap by transforming abstract ecological concepts into contextualized, learner-friendly content. The significant improvement validates the effectiveness of localized instructional materials in enhancing conceptual understanding, echoing findings from Tumbagahan (2024), Agbunag (2022), and UNESCO (2022) that contextualized modules elevate comprehension, retention, and engagement. Learners' scores improved from  $3.89 \rightarrow 25.96$  ( $p = .000$ ), proving that the MLLK is a valid and effective intervention that addresses the instructional gap in teaching mangrove ecology, while advancing eco-literacy and aligning with SDGs 4, 6, 11, 13, 14, and 15. Building on these findings of improved conceptual understanding, the next section (Figure 6) examines the Grade 10 learners' mangrove awareness mean scores (n = 84) before and after the implementation of the MLLK. This analysis highlights how the kit not only strengthened factual and conceptual knowledge but also elevated learners' ecological, social, and economic awareness of mangroves, further reinforcing its role as a transformative resource for fostering eco-literacy and sustainability.

## Mangrove Awareness of Grade 10 Learners Towards MLLK

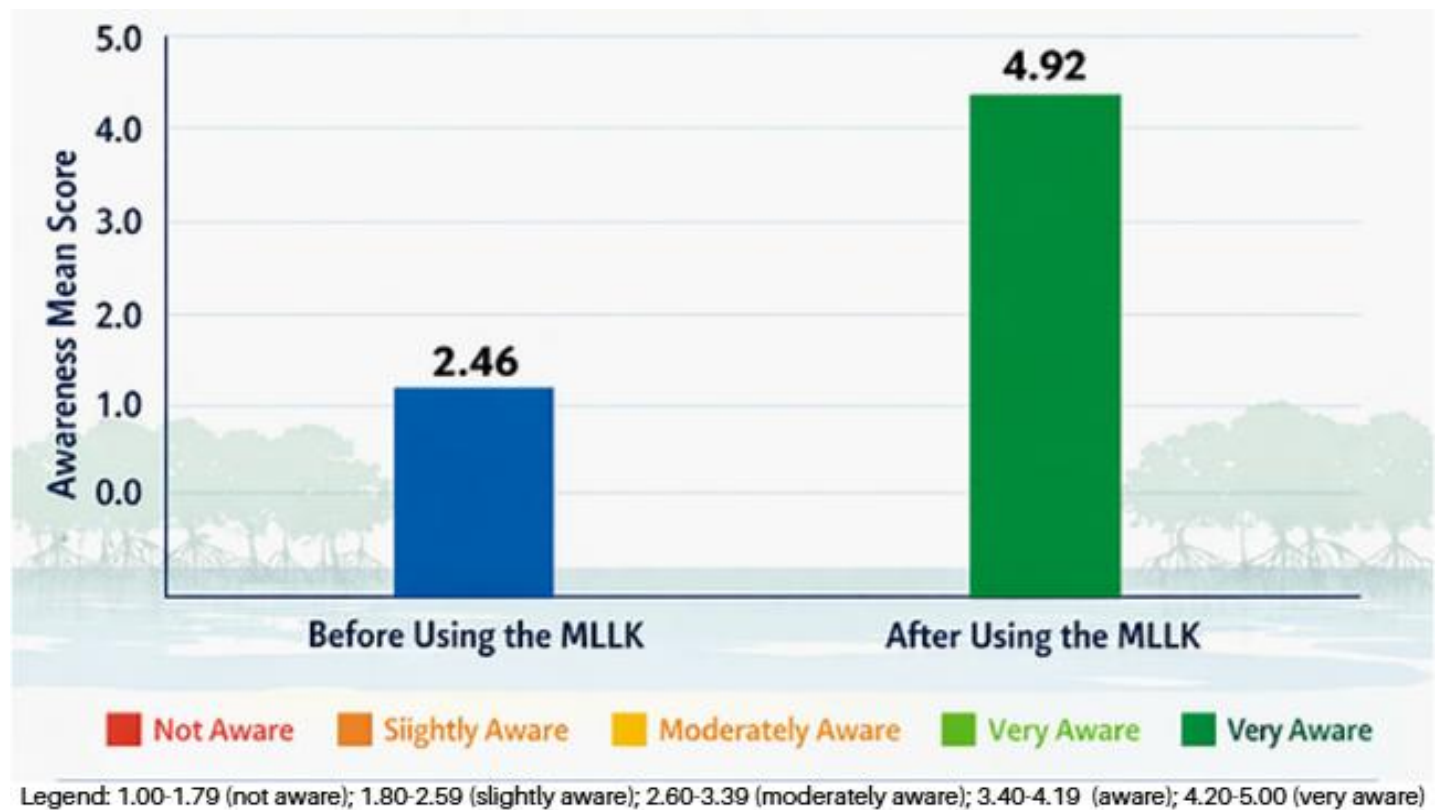


Figure12. Grade 10 Learners' Mangrove Awareness Mean Scores (n=84)

Figure 12 illustrates the significant improvement in mangrove awareness among the 84 Grade 10 learners who participated in the study before and after the implementation of the Mangrove Literacy Learning Kit (MLLK). Prior to its use, learners demonstrated only slight awareness (overall mean = 2.46/5), indicating fragmented knowledge of mangroves' ecological, social, and economic importance. After the intervention, however, awareness rose to very aware (overall mean = 4.92/5), reflecting a comprehensive understanding of mangroves as vital ecosystems. This transformation confirms that the MLLK effectively bridged instructional gaps and contextualized abstract ecological concepts into meaningful, place-based learning. Moreover, the results demonstrate the alignment of the MLLK with several Sustainable Development Goals (SDGs), specifically SDG 4 (Quality Education) through innovative instructional materials, SDG 6 (Clean Water and Sanitation) through mangroves' role as natural filters, SDG 11 (Sustainable Cities and Communities) through socio-economic benefits and coastal protection, SDG 13 (Climate Action) through resilience against floods and storm surges, SDG 14 (Life Below Water) through nursery habitats sustaining marine biodiversity, and SDG 15 (Life on Land) through species diversity and ecological adaptation. Overall, the findings affirm that contextualized instructional materials such as the MLLK can significantly elevate environmental literacy, foster stewardship, and advance global sustainability goals.

## Science Teachers' and Learners' Perceptions Towards MLLK

Table 8. Teachers' Perception of Using the Mangrove Literacy Learning Kit (MLLK)

| Factors         | Mean | Description       |
|-----------------|------|-------------------|
| Adaptability    | 4.81 | Very Satisfactory |
| Suitability     | 4.81 | Very Satisfactory |
| Usability       | 4.95 | Very Satisfactory |
| Overall Average | 4.87 | Very Satisfactory |

Legend: 1.00-1.79 (strongly disagree); 1.80-2.59 (disagree); 2.60-3.39 (neutral); 3.40-4.19 (agree); 4.20-5.00 (strongly agree)

The results in table 8 reveal that science teachers rated the Mangrove Literacy Learning Kit (MLLK) as very satisfactory across all dimensions of adaptability ( $M = 4.81/5$ ), suitability ( $M = 4.81/5$ ), and usability ( $M = 4.95/5$ ), yielding an overall average of 4.87. These findings indicate that the MLLK was perceived not only as contextually relevant but also as highly functional and appropriate for classroom use. Teachers emphasized that the kit's adaptability allowed it to be integrated seamlessly into existing lessons, while its suitability reflected strong alignment with Grade 10 Science MELCs. The highest rating in usability underscores that the MLLK was easy to implement, provided clear instructions, and supported effective teaching strategies. This positive perception aligns with the 4D Model's Disseminate phase, which highlights the importance of acceptability and perception in ensuring instructional materials are not only validated but also embraced by end-users. Overall, the teachers' responses confirm that the MLLK is a reliable, engaging, and pedagogically sound resource that enhances both teaching and learning experiences in the context of mangrove ecosystem education.

The positive perception of the MLLK reflects the 4D Model's Disseminate phase, emphasizing the importance of instructional materials being accepted by end-users. It also aligns with Kolb's Experiential Learning Theory, as the learning kit provides contextualized, activity-based experiences that move learners beyond rote memorization toward deeper ecological understanding through reflection, conceptualization, and active application.

Table 9. Learners' Perception of Using the Mangrove Literacy Learning Kit (MLLK)

| Statements                                                                          | Mean        | Description           |
|-------------------------------------------------------------------------------------|-------------|-----------------------|
| 1. The MLLK helps me understand the mangroves.                                      | 4.95        | Strongly agree        |
| 2. The presentation of concepts in the MLLK is clear and appropriate to my needs.   | 4.94        | Strongly agree        |
| 3. I could easily understand the explanations provided by the MLLK.                 | 4.85        | Strongly agree        |
| 4. I learned useful information not mentioned in the pre-test after using the MLLK. | 4.93        | Strongly agree        |
| 5. The activities are suited for the particular time allotment.                     | 4.88        | Strongly agree        |
| 6. Activities and tasks given in the MLLK were achievable.                          | 4.93        | Strongly agree        |
| 7. I had fun reading and doing all activities required in the MLLK.                 | 4.93        | Strongly agree        |
| 8. MLLK used words and terms suited to my reading comprehension.                    | 4.96        | Strongly agree        |
| 9. MLLK inspired and encouraged me to learn more about the mangrove ecosystem.      | 4.92        | Strongly agree        |
| 10. I want to use MLLK in the digital mode of learning next time.                   | 4.87        | Strongly agree        |
| <b>Overall Mean</b>                                                                 | <b>4.92</b> | <b>Strongly agree</b> |

*Legend: 1.00-1.79 (strongly disagree); 1.80-2.59 (disagree); 2.60-3.39 (neutral); 3.40-4.19 (agree); 4.20-5.00 (strongly agree)*

The results in Table 9 show that learners strongly agreed across all statements, with an overall mean of 4.92/5. This indicates that the MLLK was highly acceptable and effective in supporting their learning. The highest rating was observed for the statement "MLLK used words and terms suited to my reading comprehension" ( $M = 4.96/5$ ), confirming that the glossary and contextualized language made the material accessible to diverse learners.

Learners also emphasized that the MLLK helped them understand mangroves ( $M = 4.95/5$ ), presented concepts clearly ( $M = 4.94/5$ ), and provided useful information beyond the pretest ( $M = 4.93/5$ ). The activities were described as achievable and enjoyable, with ratings of 4.93/5 for both engagement and suitability to time allotment. Importantly, learners reported that the MLLK inspired them to learn more about the mangrove ecosystem ( $M = 4.92/5$ ) and expressed interest in using it in digital mode in the future ( $M = 4.87/5$ ).

These findings align with the Disseminate phase of the 4D Model, which emphasizes acceptability and perception. While the Develop and Validate phase ensured accuracy and reliability, the Disseminate phase confirmed that the MLLK was not only pedagogically sound but also engaging, motivating, and learner-friendly. The consistently high ratings demonstrate that the MLLK successfully fostered conceptual understanding, curiosity, and positive attitudes toward mangrove conservation.

## DISCUSSION

The development of the Mangrove Literacy Learning Kit (MLLK) addressed the instructional gaps identified during the needs assessment with administrators and science teachers. Thematic Analysis following Braun and Clarke's (2021) six-phase framework revealed recurring themes of adaptability, suitability, and usability, which became the guiding principles in designing the learning kit. Administrators emphasized the motivational role of contextualized materials, while teachers highlighted the need for interactive, inquiry-based approaches to make ecological concepts tangible. These perspectives converged on the necessity of a localized instructional resource that bridges curriculum standards with real-world ecological contexts.

The results of the pilot implementation and validation confirmed that the MLLK was pedagogically sound, scientifically accurate, and learner-friendly. Teachers rated the kit very satisfactory across all dimensions, with usability receiving the highest mean score (4.95), underscoring its practicality and ease of integration into classroom instruction. Learners likewise expressed strong agreement (overall mean = 4.92) that the MLLK enhanced their understanding of mangroves, clarified scientific concepts, and inspired further interest in environmental conservation. These findings validate the effectiveness of contextualized instructional materials in promoting conceptual understanding and eco-literacy.

The inclusion of features such as interactive activities, authentic visuals, trivia icons, reflection prompts, and a glossary enriched the learning experience by balancing academic rigor with creativity. Learners described the activities as "tricky but thrilling," reflecting the kit's ability to challenge while sustaining engagement. The glossary further enhanced accessibility, reducing confusion over technical terms and supporting comprehension across diverse learners. Beyond these pedagogical features, the Mangrove Literacy Learning Kit (MLLK) encompasses a wide range of themes, including mangrove parts and ecology, Philippine mangrove species, biodiversity and wildlife, wetlands and coastal ecosystems, climate change and blue carbon, fisheries and food security, environmental conservation, environmental laws and policies, Philippine environmental issues, rehabilitation and conservation success stories, and environmental leadership and advocacy. To strengthen learner engagement, the kit integrates inquiry-based activities, reflection journals, and structured prompts that encourage critical thinking.

Statistical analysis reinforced these qualitative insights. The use of mean scores and standard deviation demonstrated consistent positive perceptions among both teachers and learners, while frequency counts and thematic clustering highlighted recurring priorities such as contextual relevance, clarity of presentation, and learner engagement. Together, these results provide robust evidence that the MLLK is not only acceptable but also effective in enhancing Grade 10 learners' conceptual understanding of biodiversity and ecosystems.

In alignment with the modified 4D Model (Define + Ideate, Design + Development, Develop + Validation, Disseminate: Acceptability & Perception), the study demonstrated that instructional material development is a dynamic and iterative process. By integrating ideation, validation, and perception assessment, the MLLK evolved into a contextualized, learner-centered resource that bridges theory with practice, global science with local realities, and knowledge with values.

## CONCLUSION

This study developed and validated the Mangrove Literacy Learning Kit (MLLK) to address the instructional gaps identified in teaching biodiversity and mangrove ecology. Anchored on the modified 4D Model, the kit was systematically designed, validated, and pilot-tested to ensure scientific accuracy, pedagogical soundness, and learner-friendliness. Validation results confirmed that the MLLK enhanced students' understanding of mangroves, clarified abstract ecological concepts, and fostered eco-literacy and conservation attitudes. By situating lessons within the mangrove ecosystem of Bayug Island, Iligan City, Philippines, the learning kit provided meaningful, place-based learning experiences that bridged theory and practice. Importantly, the study solved the research gap of lacking contextualized, ecologically grounded instructional materials in secondary science education. The MLLK thus stands as a model for integrating curriculum standards with local ecological realities, promoting both academic achievement and environmental stewardship, and offering a strategic intervention for advancing sustainability education in the Philippines.

Beyond its immediate classroom application, the learning kit contributes to advancing sustainability education in the Philippines, aligning with global calls for contextualized instruction and the Sustainable Development Goals (SDGs 4, 6, 11, 13, 14, and 15). The MLLK demonstrates that contextualized, ecologically grounded instructional materials can transform science education by making abstract concepts accessible, inspiring conservation values, and empowering learners to become active stewards of their environment.

## RECOMMENDATION

Based on the findings, the study recommends integrating the Mangrove Literacy Learning Kit (MLLK) into the science curriculum, particularly in ecology and biodiversity units, ensuring that it remains aligned with DepEd standards while reflecting local environmental realities.

For teachers, the MLLK could serve as a helpful resource to gradually shift instruction from lecture-based to inquiry-based approaches. Incorporating visuals, models, and reflective discussions may make abstract concepts more concrete and meaningful, while the inclusion of indigenous knowledge and community narratives could further enrich classroom learning.

For administrators, supporting professional development opportunities, allocating resources, and fostering partnerships with government agencies, NGOs, and local communities may strengthen implementation. Establishing monitoring and evaluation mechanisms could also help ensure adaptability and sustainability over time.

To enhance sustainability outcomes, the MLLK might be expanded to include: Eco-literacy activities such as mangrove monitoring and coastal clean-ups. Community engagement initiatives that build resilience in coastal communities. Entrepreneurial projects (e.g., eco-tourism, mangrove-based crafts) that link conservation with livelihood opportunities, thereby supporting local economic resilience. Climate change education and disaster risk reduction strategies to prepare learners as proactive stewards of their environment. Continued alignment with the United Nations Sustainable Development Goals (SDGs), particularly SDG 4, SDG 6, SDG 11, SDG 13, SDG 14, and SDG 15.

For future research, it may be beneficial to conduct longitudinal studies to examine the long-term impact of the MLLK on learners' ecological literacy, conservation behaviors, and community resilience. Comparative studies could also explore its adaptability to other ecosystems such as coral reefs, wetlands, and forests, thereby broadening its contribution to sustainability education.

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