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Voices of the sea: community perspectives on indigenous languages, ecological knowledge, and mangrove conservation education

Voces del mar: perspectivas comunitarias sobre las lenguas indígenas, el conocimiento ecológico y la educación para la conservación de los manglares

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ABSTRACT. This paper explores how community-authored multilingual ethnotestimonials serve as both cultural documentation and pedagogical intervention in the context of mangrove conservation education. Drawing from eight seafaring cultures, including Wayuu, Yucatec Maya, Mopán Maya, Q'eqchi' Maya, Garifuna, Miskitu, Ulwa, Burmese, Bahasa and Belizean Kriol, I analyze a series of reflective Introductions to conservation textbooks written in Indigenous languages and translated into either English or Spanish. These ethnotestimonials reveal how language, place, and ecological knowledge are intertwined in the lived experiences of coastal communities, and how these connections can inform more inclusive and effective conservation education. I propose that these ethnotestimonials are not only vehicles of memory and identity but also instruments for hybridizing ecological knowledge systems and operationalizing decolonial science education. This work supports the foundation for the first author's previously published frameworks on the *Ethnotranslation Model* and the *Hybridization Hypothesis of Ecological Knowledge Systems*, and informed the development of a related Maya-language master's thesis project, which found that culturally resonant, mother-tongue instruction improved both science learning and cultural identity among students.

KEYWORDS: Mangrove conservation; Indigenous knowledge; Multilingual education; Environmental education; Science education; Language revitalization; Biocultural education; Ethnotranslation; STEM.

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RESUMEN. Este artículo explora la función de los etnotestimonios multilingües, creados por las propias comunidades, como herramientas de registro cultural y como estrategias pedagógicas enfocadas en la enseñanza de la preservación de los manglares. A partir de ocho culturas marineras, incluyendo wayuu, maya yucateco, maya mopán, maya q'eqchi', garífuna, miskitu, ulwa, birmano, bahasa y criollo beliceño, analizo una serie de introducciones reflexivas a libros de texto sobre conservación, escritas en lenguas indígenas y traducidas al inglés o al español. Estos etnotestimonios revelan cómo la lengua, el lugar y el conocimiento ecológico se entrelazan en las experiencias de las comunidades costeras, y cómo estas conexiones pueden fundamentar una educación para la conservación más inclusiva y eficaz. Propongo que estos etnotestimonios no son solo vehículos de memoria e identidad, sino también instrumentos para hibridar los sistemas de conocimiento ecológico y para poner en práctica la educación científica descolonial. Este trabajo refuerza los marcos teóricos previamente establecidos por el autor primero sobre el *Modelo de Etnotraducción* y la *Hipótesis de la Hibridación de los Sistemas de Conocimiento Ecológico*. De igual manera, contribuyó a un proyecto de maestría en lengua maya, donde se halló que enseñar en la lengua materna, adaptándose a la cultura local, mejora positivamente la adquisición de conocimientos científicos y la identidad de los estudiantes.

PALABRAS CLAVES: Conservación de manglares; Conocimiento indígena; Educación multilingüe; Educación ambiental; Educación científica; Revitalización lingüística; Educación biocultural; Etnotraducción; STEM.

Introduction

For millennia, Indigenous and Creole communities have maintained reciprocal relationships with the environments they inhabit, viewing landscapes and ecosystems not only as ecological resources but also as cultural and spiritual homelands (Berkes, 2018; Cajete, 2000; Kimmerer, 2013). Yet the dual forces of environmental degradation and linguistic marginalization now threaten these relationships. Formal education systems, often delivered in dominant languages, contribute to cultural disorientation[1] and the erosion of ecological knowledge systems by disrupting the intergenerational transmission of language, identity, and place-based knowledge systems (Aikenhead & Jegede, 1999; Battiste, 2013; Harmon & Maffi, 2002; Maffi, 2005). This paper centers multilingual, community-authored ethnotestimonials that were written as Introductions to mangrove conservation textbooks in nine languages. Rather than being centrally curated, each contribution emerged from an open-ended prompt: "What would you like to say about this book and this project?[2]" In each case, the book referred to the newly created mangrove conservation text written in the contributor's home language. The project encompassed a broader Marine Conservation without Borders (MCB) led initiative to advance ocean literacy and ecosystem conservation through multilingual, biocultural education. These books were first mentioned in Thigpen (2025).

Hilario Poot Cahun's master's thesis later served as a key conceptual bridge between this mangrove prototype phase and the development of the Maya-language STEM Plus textbooks. While his research is not the focus of this paper, his classroom trials provided empirical validation for several design principles first tested through the ethnotestimonials and the mangrove prototypes, demonstrating how insights from this phase could be translated into sustained, culturally grounded science education for Indigenous primary schools in the same ecoregion.

From Regional Prototypes to Maya Classrooms

An often-overlooked aspect of the Maya STEM Plus project is that the educational content evaluated during the pilot was not originally developed for Maya-speaking students in Quintana Roo. Rather, the materials emerged from a much longer process of experimentation involving conservation practitioners, scientists, Indigenous educators, fishers, and community collaborators throughout the greater Caribbean Basin and Mesoamerica. The project's multinational and multilingual developmental history has at times been obscured when viewed primarily through the lens of a single educational setting, language community, or disciplinary framework.

[1] In this paper, *Cultural Disorientation* is defined as the loss or consequence of language shift, environmental degradation, weakening of the cultural, linguistic, and ecological reference and the marginalization of local knowledge systems.
points through which individuals and communities understand [2] The prompt was intentionally broad. Rather than soliciting their place in the world. It often accompanies language shift, responses about predefined themes, contributors were invited environmental degradation, and educational systems that to determine the content and direction of their own marginalize local knowledge traditions, resulting in the erosion testimonials. This approach is consistent with *Relational* of biocultural identity and ecological stewardship. Unlike *Learning* (Thigpen, 2026) and Indigenous dialogic traditions earlier uses of the term, which primarily describe difficulties such as *Tsikbal* (Castillo Cocom et al., 2015) which emphasize associated with cross-cultural encounters, the present participant agency and reciprocal knowledge exchange rather definition conceptualizes cultural disorientation as a than researcher-directed extraction. (Poot Cahun, 2025)

Discussions concerning a second phase of development began during October and November 2019. During this period, prototype mangrove conservation materials were shared directly with linguistic and community stakeholders in Belize, México, Guatemala, Honduras, and Panamá. These face-to-face meetings provided opportunities to distribute materials in their respective languages, discuss future adaptations, and explore potential classroom pilots and community-based implementation strategies. The long-term vision already included expansion into Indigenous and Creole linguistic communities throughout the region, including Maya-speaking communities in México. At the time, however, Belize and Honduras appeared to be the most likely locations for the next phase of implementation due to the strength of existing partnerships and the coastal focus of the mangrove, fisheries, and marine conservation materials. Although discussions were underway in multiple countries, it was anticipated that Phase 2 would likely begin in one of these two nations.

These plans were interrupted by the emergence of the COVID-19 pandemic in early 2020, which brought border closures, travel restrictions, and delays to community-based educational initiatives throughout the region. As the pandemic unfolded, opportunities for in-person educational implementation became increasingly limited. During this period, the project temporarily expanded beyond conservation education to include multilingual COVID-19 community health materials. Working with Indigenous, Creole, and minority-language communities representing approximately fifteen languages, the first author developed culturally and linguistically adapted community health materials that provided an additional environment in which emerging *Ethnotranslation* methods continued to evolve.

Many of the multilingual conservation education and community health materials developed during this period, together with related educational resources produced through the Marine Conservation without Borders (MCB) research program, have since been archived in the Marine Conservation without Borders Collection at the Archive of the Indigenous Languages of Latin America (AILLA) (Archive of the Indigenous Languages of Latin America, n.d.), where they are freely available for download by educators, researchers, students, and community members.

As opportunities for implementation gradually re-emerged, collaborations with Maya educators, Indigenous primary schools, the *Universidad Intercultural Maya de Quintana Roo* (UIMQROO), and the *Secretaría de Educación de Quintana Roo* (SEQ) created an unexpected beginning for the next phase of the project. Rather than commencing in Belize or Honduras as originally anticipated, large-scale implementation first emerged in Maya-speaking communities of Quintana Roo. Although the starting point differed from earlier expectations, the broader trajectory remained unchanged: the development of multilingual, biocultural educational materials capable of supporting language revitalization, ecological literacy, and conservation across diverse linguistic communities.

Consequently, the Maya project became the first large-scale educational implementation of a framework that had already undergone years of conceptual development, multilingual experimentation, and iterative refinement across multiple countries and linguistic communities.

This history is important because it demonstrates that the materials evaluated by Poot Cahun (2025) were not locally produced content created specifically for a single educational context. Instead, they represented a synthesis of scientific knowledge, conservation experiences, linguistic innovations, and pedagogical strategies originating from diverse ecological, cultural and epistemic settings. Chapters authored by taxonomists, fisheries scientists, primatologists, ornithologists, marine conservationists, and Indigenous educators were adapted (ethnotranslated) into a common Maya-language epistemological framework. In many cases, the species, examples, and narratives were modified substantially during this process. Some chapters were rewritten around species more relevant to Maya students, while others were linguistically and culturally recontextualized through the *Ethnotranslation Model* and community review. (Thigpen, 2025, Thigpen, 2026)

Viewed in this light, the significance of the Maya pilot extends beyond the evaluation of individual educational materials. The project effectively tested whether scientific knowledge developed across multiple countries, disciplines, ecosystems, and cultural contexts could be successfully integrated into a coherent Indigenous-language educational system. The positive outcomes reported by Poot Cahun (2025) therefore suggest not merely the effectiveness of particular lessons, but the viability of an educational framework capable of interoperating across diverse knowledge traditions, scientific disciplines, and regional contexts.

While Poot Cahun's (2025) research is not the focus of this paper, his classroom trials provided empirical validation for several design principles first tested through the ethnotestimonials and mangrove prototypes, demonstrating how insights from this phase could be translated into sustained, culturally grounded science education for Indigenous primary schools in the same ecoregion.

Each mangrove prototype examined in this study was developed under the editorial and scientific direction of the first author and further developed in Tegucigalpa, Honduras with Grazzia Matomoros Erazo and José Antonio Romero Durón, and ethnotranslated by a respected knowledge keeper and cultural protector from the corresponding linguistic community. These Indigenous and Creole ethnotranslators were recognized on the cover as coauthors and were also cited as coauthors in academic references to the texts, granting full credit for their linguistic and ecological expertise (Thigpen, 2026). The Indigenous and Creole coauthors, linguistic communities, and community affiliations represented in this phase of the project are summarized in **Table 5.**

One guiding instruction given to each local coauthor [ethnotranslator] was to forget conventional translation methods and to simply "make it work", to render scientific ideas in ways that resonated with local knowledge systems, cultural values, and, where appropriate, community cosmologies. This liberated the process from the constraints of Western translation methodologies, especially those ill-suited for converting biological concepts into historically oral languages. Additionally, this gave the first author the opportunity to observe how each collaborator would interpret the instruction to ignore convention and just make it work. Each contributor approached the task differently, some created neologisms, others used transliteration for scientific terms, and all applied their deep community-specific insight. This diversity of approaches became a valuable source of

learning. The first author was able to identify what worked best by listening to and learning from their Indigenous and Creole coauthors and collaborators.

These early experiments directly informed the next stage of curriculum development for the Maya project. The development of the early Maya-language textbooks followed an intentionally iterative design process in which multiple pedagogical, linguistic, and curricular strategies were treated as working hypotheses and evaluated through practice. Some approaches proved effective and were retained, while others were modified or abandoned as new observations accumulated. The textbooks that ultimately emerged therefore reflect not a predetermined model, but a process of continual experimentation, assessment, and refinement.

To preserve the integrity of concurrent classroom-based evaluation (Poot Cahun, 2025), these design decisions were not disclosed during the active research phase. This allowed for independent assessment of how students and teachers engaged with the materials, free from influence by ongoing methodological refinement. While early versions of the textbooks functioned as effective prototypes of biocultural education, subsequent iterations led to a more streamlined and replicable set of design principles grounded in community insight and pedagogical performance.

These two Maya-language textbooks served both as a formal data source for Hilario Poot Cahun's master's thesis and as a testbed for integrating and stress-testing methods derived from these earlier multilingual mangrove prototypes (Thigpen and Poot Cahun 2022, Poot Cahun and Thigpen 2023) derived from these earlier multilingual mangrove prototypes. The first author conducted informal, unstructured conversations with Maya university research assistants and professors at *la Universidad Intercultural Maya de Quintana Roo* (UIMQROO), teachers from the *Departamento de Educación Indígena de los Servicios Educativos de Quintana Roo* (SEQ), and the family members of Indigenous primary school students throughout the two-year trial. These discussions revealed how the materials were received and which elements resonated or did not. However, to protect the thesis's integrity, many of these reflections were not shared with Hilario or other participants during the active research phase. The aim was to quietly observe how well previously successful techniques such as ethnobiological metaphors, community-driven translation, and visual-linguistic alignment performed when brought together into a single, structured classroom setting.

The multilingual adaptations presented here highlight multiple, layered processes. *Ecological Translanguaging* appears as a pedagogical strategy within texts that blend local and dominant languages for clarity or rhetorical effect. *Ethnotranslation* refers more broadly to the act of re-articulating scientific content through culturally grounded narrative forms. These processes often give rise to hybridized texts where distinct ecological knowledge systems remain visible but interdependent. Together, they contribute to a pluriversal approach to science education, in which no single worldview is privileged, and multiple epistemologies are permitted to coexist in generative tension. (Thigpen, 2025; Thigpen, 2026)

These texts offer a rare polyphonic reflection on conservation, language, and education. Written by elders, teachers, and community leaders, they ground the mangrove prototypes in the lived experience and moral

authority of each community. I argue that the ethnotestimonials and methods learned here are more than introductory texts: they represent an emergent methodology for re-centering voice, place, and language in science education.

While related to traditions of testimonial literature and participatory narrative, ethnotestimonials differ in that they are embedded within scientific and educational materials and function simultaneously as narrative, data, and methodological intervention. Unlike conventional testimonials, which are often retrospective accounts of lived experience, ethnotestimonials are forward-facing and actively shape how knowledge is structured, taught, and transmitted within multilingual educational contexts.

This paper asks: What are the pedagogical and epistemological implications of allowing Indigenous and Creole communities to author their own multilingual environmental science materials? How do these ethnolinguistic adaptations reshape not only language but the structure and purpose of science education?"

As this paper will show, each version of the mangrove prototype is not merely a translation, but a cultural re-articulation of ecological education. The adaptations from poetic testimony in the Wayuu edition to the ecological translanguaging of the Belizean Kriol version demonstrate how multilingual, community-led co-authorship can shape not just the language of science education, but its structure, tone, and pedagogical function.

This re-articulation of science education through community-led, multilingual design laid the groundwork for two subsequent manuscripts: the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen 2025), and *Ethnotranslation and Biocultural Education: Bridging Indigenous Knowledge and STEM Curricula (Thigpen, 2026)*. These subsequent works formalize concepts and methods that emerged inductively from the empirical and collaborative processes documented in this study. The *Hybridization Framework* emerged from early insights documented here regarding how culturally distinct ecological knowledge systems, Indigenous or Creole ecological epistemologies and Western ecological science can coexist without subsumption in educational materials. Likewise, the *Ethnotranslation Model* formalizes the methodological processes first developed during the creation of the multilingual mangrove prototypes presented here, offering a replicable approach to preserving linguistic and cultural integrity while maintaining scientific coherence. Together, these works build directly upon the field practices and collaborative strategies initiated during the mangrove prototype phase of the STEM Plus project.

The polylingual mangrove prototypes documented here served as the empirical foundation for the subsequent development of the *Ethnotranslation Model* (Thigpen, 2026) and contributed to the observations that later informed the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen, 2025). These methods were subsequently applied in the development and pilot testing of MCB's Maya-language STEM Plus curricula in Quintana Roo, Mexico, where Poot Cahun (2025) documented positive outcomes related to linguistic and cultural identity, environmental learning, and community engagement. Together, these works represent successive stages in the evolution of a broader biocultural educational framework, progressing from multilingual prototype development, to methodological formalization, to theoretical articulation, and

finally to classroom-based evaluation.

Contribution Statement

This paper makes three primary contributions. First, it introduces *ethnotestimonials* as a distinct form of community-authored scientific discourse that integrates narrative, ecological knowledge, and linguistic expression. Second, it demonstrates how these texts function as sites of epistemological production, where Indigenous and Creole knowledge systems are not merely represented but actively shape the structure and meaning of ecological education. Third, it establishes that multilingual, community-authored curriculum development can serve as a generative methodological space, producing insights that informed the subsequent development of the *Ethnotranslation Model* and the *Hybridization Hypothesis of Ecological Knowledge Systems*. In this sense, the present study represents the empirical and narrative foundation from which these later theoretical frameworks emerged.

Throughout this paper, the term multilingual is used to describe the educational materials and collaborations under discussion. However, the processes documented here extend beyond the production of educational materials in multiple languages. Knowledge moved among linguistic communities through iterative cycles of co-development, ethnotranslation, validation, adaptation, and reuse. In this sense, the project may be more accurately understood as an emerging example of a *Polylingual Education*[3]*Model*, in which knowledge is co-developed, translated, validated, adapted, and transmitted across multiple linguistic communities, with each linguistic community and its language serving not merely as a vehicle of instruction but also as a site of knowledge generation (Thigpen 2026).

Methods

This study employs qualitative discourse analysis on a corpus of multilingual Introductions to prototype mangrove conservation texts produced through a participatory curriculum development process led by Marine Conservation without Borders. Contributions were collected from speakers of Wayuu (Colombia/Venezuela), Maya Yucatec (Belize, México), Maya Mopán, and Q'eqchi' Maya (Belize / Guatemala), Kriol (Belize), Miskitu and Ulwa (Nicaragua / Honduras), Garifuna (Belize / Guatemala / Honduras / St. Vincent Nicaragua), Burmese (Myanmar) and Bahasa (Indonesia). The linguistic communities, geographic origins, and developmental lineage of these prototype adaptations are summarized in **Table 1**, while the Indigenous and Creole coauthors who participated in their development are identified in **Table 5**.

Relational learning as methodological foundation

In addition to qualitative discourse analysis, this study is grounded in a *Relational Learning* orientation as articulated within the *Ethnotranslation Model* (Thigpen, 2026). *Relational Learning* refers to methodological insight generated through sustained, trust-based engagement with a core group of Indigenous and Creole collaborators during the early mangrove prototype phase, including Belizean Kriol, Maya, Garifuna, and Mestizo fisher folk whose livelihoods are directly embedded in mangrove and littoral ecosystems. These long-term interactions

[3] *Polylingual Education* refers to educational systems in which knowledge is co-developed, ethnotranslated, validated, adapted, and transmitted across multiple linguistic communities, with each linguistic community and its language serving not merely as a vehicle of instruction but also as a site of knowledge generation.

informed transferable design principles related to narrative structure, metaphor use, visual / linguistic alignment; and epistemological and pedagogical framing.

Following this foundational phase, additional linguistic groups were invited to ethnotranslate the mangrove prototypes using methods derived from earlier *Relational Learning*. While extended engagement with these later collaborators was intended, funding constraints limited the depth of interaction. Nonetheless, the relationally derived methods proved effective across diverse ecoregions, species ranges, and coexisting linguistic communities, demonstrating the methodological portability of the *Ethnotranslation Model* (Thigpen, 2026) and aligning with the cross-contextual dynamics described in the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen, 2025).

The analysis followed an inductive thematic approach, whereby codes and themes were developed iteratively from the data rather than being imposed a priori. *Ethnotestimonials* were treated as units of analysis and examined for recurring patterns in narrative structure, metaphor use, expressions of ecological relationships, and positioning of language within knowledge generation and transmission. Cross-linguistic comparison focused on identifying both convergent themes and culturally specific divergences across the nine linguistic communities. Particular attention was given to how ecological concepts were framed, how authority was constructed within the text, and how relationships between humans and mangrove ecosystems were articulated. These patterns were then interpreted in relation to broader questions of epistemology, pedagogy, and multilingual curriculum design.

While the Belizean Kriol edition did not contain an Introduction in the style of the other prototypes, it included a Dedication that reflected the voice and intent of its community coauthors. Although structurally different, this Dedication conveyed cultural, ecological, and pedagogical perspectives consistent with the goals of the project. For the purposes of this study, we examined and compared the content of this Kriol mangrove prototype Dedication alongside the Introductions and content from the other editions, noting both its unique form and its thematic resonance with the broader corpus.

In addition to the qualitative discourse analysis and *Relational Learning* presented here (Thigpen, 2026), this study is further grounded by the complementary research of Hilario Poot Cahun (2025), whose master's thesis incorporated both quantitative and ethnographic methods.

Poot Cahun's fieldwork was conducted within a broader collaborative research program established through a tripartite partnership among Marine Conservation without Borders (MCB), the *Universidad Intercultural Maya de Quintana Roo* (UIMQROO), and the *Departamento de Educación Indígena of Servicios Educativos de Quintana Roo* (SEQ) (MCB & UIMQROO, 2024; MCB & SEQ, 2022). The research operated within a formal institutional governance framework established through separate research agreements between MCB and UIMQROO and between MCB and SEQ. Together, these agreements defined the governance structure, institutional responsibilities, and procedures governing project implementation. The SEQ–MCB agreement was executed on behalf of SEQ by Mtra. Ana Isabel Vázquez Jiménez, Director General of SEQ, and Dra. Luz María Abuxapqui González, *Coordinadora General de Educación Básica*.

As the governmental educational authority, SEQ authorized research activities in the participating Indigenous primary schools, while project implementation and site access were coordinated through MCB as the designated implementing entity in accordance with the SEQ–MCB agreement (MCB & SEQ, 2022; MCB & UIMQROO, 2022).

Under the direction of Robert C. Thigpen III as project leader (Poot Cahun, 2025; SEQ, 2022), MCB served as the coordinating and implementing organization responsible for curriculum development, project coordination, implementation management, and oversight of the broader research environment, while UIMQROO and SEQ provided academic, institutional, and educational support. In addition to reviewing the educational materials, SEQ required that proposed Maya-language terminology and neologisms be evaluated by its Maya Commission, composed of Indigenous educators, school administrators, supervisors, and pedagogical advisors affiliated with the Department of Indigenous Education, prior to classroom implementation. Both the pilot and final versions of the educational materials were subject to this review process (MCB & SEQ, 2022), providing an additional layer of linguistic, cultural, and educational validation beyond the curriculum development team itself. The broader partnership framework and implementation structure are also documented in Poot Cahun's (2025) thesis, which describes the collaboration among the partner organizations; MCB, UIMQROO, and SEQ throughout the development and pilot testing of the Maya-language STEM Plus materials.

The MCB implementation framework was intentionally designed to support multiple downstream research projects, student researchers, institutional collaborations, and educational initiatives operating within a common governance and implementation environment.

School selection was carried out by SEQ following the establishment of the tripartite research framework. As project leader, Robert C. Thigpen III established a limited set of project requirements to guide school selection, including minimum and maximum student enrollment thresholds necessary to support meaningful statistical analyses and project logistics, together with the inclusion of both inland and coastal communities. SEQ retained responsibility for the final selection of participating schools. During project planning, the possibility of selecting schools with exceptionally strong Maya-language literacy was considered; however, the project leader recommended against this approach in favor of a more heterogeneous sample. The objective was to approximate, as closely as practical within the constraints of an applied educational intervention, a sample that reflected the diversity of Indigenous primary schools rather than one intentionally biased toward the strongest Maya-language settings.

Beyond the general selection parameters established during project planning, the specific weighting of factors used by SEQ in selecting participating schools was not disclosed to the project leader. Nevertheless, the resulting sample included schools that differed substantially in geographic location, community characteristics, student enrollment, and levels of Maya-language use. Although several communities within the Maya Zone are recognized for substantially stronger Maya-language vitality than some of the participating schools, the final sample was not restricted to those settings. This indicates that maximizing Maya-language use was not the sole consideration in school selection and resulted in a more

heterogeneous sample than would have been obtained through purposive selection of only the strongest Maya-speaking communities. Consequently, the educational materials were evaluated across a broader range of sociolinguistic and educational contexts, improving the representativeness of the pilot and increasing the potential applicability of the findings to Indigenous primary schools throughout the region.

While this paper offers an accessible read, it performs significant conceptual and methodological groundwork. It addresses a series of interrelated hypotheses concerning knowledge portability, ecological interoperability, linguistic knowledge generation, multilingual curriculum design, and community coauthorship. Together, these ideas contributed to the expansion of the project's curricular framework, enabling the development of multilingual educational materials that integrate aquatic, marine, and terrestrial ecological knowledge systems across international, cultural, linguistic, and disciplinary boundaries.

H-1. Community-authored, multilingual ethnotestimonials function as one mechanism through which the *Hybridization of Ecological Knowledge Systems* occurs, integrating place-based ecological knowledge, cultural memory, and scientific understandings of mangrove ecosystems within a shared educational framework, while structural and stylistic divergences serve as expressions of curriculum sovereignty, cultural relevance, ecological continuity, and methodological portability.

H-2. Ecological Curriculum Portability Hypothesis: Ecological and conservation knowledge organized around a shared ecological curriculum core can be successfully rearticulated through ethnotranslation across multiple linguistic communities that share ecological systems, species assemblages, ecological processes, and conservation challenges, without requiring the development of entirely separate ecological curricula for each language group.

Research Questions:

1. **Cultural, Epistemic and Pedagogical Function:**
   How do community-authored, multilingual ethnotestimonials function simultaneously as cultural documentation, pedagogical tools, and epistemic resources in mangrove conservation education?
2. **Language, Place, and Ecological Knowledge:**
   What insights do these ethnotestimonials offer into the relationships among language, place, and ecological knowledge in seafaring Indigenous and Creole communities?
3. **Hybridization and Decolonial Education:**
   In what ways can these multilingual ethnotestimonials contribute to the *Hybridization of Ecological Knowledge Systems* and support decolonial frameworks in science education?
4. **Ethnotranslation as Methodological Reframing:**
   How does the *Ethnotranslation Model*, as practiced by Indigenous and Creole coauthors, challenge and reframe conventional approaches to translation in science curricula?
5. **Linguistic and Cultural Divergence Across Editions:**
   What structural, linguistic, and cultural distinctions emerge across the localized editions of mangrove conservation texts, and how do these affect their pedagogical function?
6. **Scalability, Portability and Curriculum Design:**

How can the insights gained from these ethnotestimonials and prototype texts inform the development of scalable, portable, culturally resonant, and linguistically inclusive STEM Plus curricula?

Belize, Panamá, Guyana, and Suriname may represent ideal proof-of-concept environments because each contains a relatively small number of major linguistic communities distributed across shared ecological systems. In principle, a common ecological curriculum could be adapted through the *Ethnotranslation Model* for every major linguistic group within a country, allowing researchers to evaluate whether multilingual conservation education can achieve national-scale coverage without requiring the development of entirely separate ecological curricula for each language community.

Each Introductions contributor was asked by their community's ethnotranslator to reflect on the role of language, the importance of mangroves, and the goals of multilingual education. They were to share exactly what they thought of their book and the project. Translations into English and / or Spanish accompanied the originals. Themes were identified inductively, with attention to metaphors, affective language, and conceptual linkages among land, sea, and language.

The multilingual mangrove prototypes developed for this project were designed not as final products, but as pedagogical and methodological learning tools, as were MCB's 4th and 5th grade Maya-language STEM Plus prototypes (Thigpen & Poot Cahun 2022; Poot Cahun, & Thigpen 2023) later used in Poot Cahun's (2025) master's thesis. Each prototype enabled the project leader to experiment with how ecological concepts, narrative tone, visual structure, and linguistic adaptation functioned across distinct cultural and linguistic contexts. The goal was to determine not only what scientific and ecological concepts should be communicated, but also how they could be communicated most effectively within different communities and knowledge traditions.

The broader goal the first author was not simply to create multilingual conservation education materials, but to create educational experiences that "*speak to the heart and teach the mind*." Recent scholarship has likewise emphasized that language revitalization efforts should strengthen not only Indigenous languages themselves but also the social prestige and educational opportunities of their speakers (Sima Lozano et al., 2014). The prototypes were therefore designed to communicate scientific concepts in ways that remained culturally meaningful, emotionally resonant, and relevant to contemporary environmental challenges (Thigpen, 2026). This approach reflects an effort to develop educational materials capable of engaging both the intellectual and emotional dimensions of learning while connecting language, identity, culture, and ecology. In this sense, the project sought not only to transmit information, but also to cultivate stewardship, strengthen linguistic and cultural continuity, and create pathways through which communities could carry both their knowledge and their languages into the future. Ultimately, the goal was to help ensure that Indigenous and local languages remained not only languages of memory and heritage, but also languages of learning, problem-solving, innovation, and hope (Cru, 2016).

Insights gained through these early experiments informed the development of the 4th and 5th grade STEM Plus textbooks, co-developed for Indigenous primary schools in the Maya Zone of Quintana Roo, México,

and later used in three university classrooms in México and Belize.

These Maya-language prototype textbooks served not as endpoints, but as a second-generation testbed where lessons derived from the multilingual mangrove prototypes could be combined, refined, and intentionally stress-tested within formal educational settings. Later evaluated in situ through Poot Cahun's (2025) master's thesis research, these materials provided an opportunity to assess which approaches remained effective when integrated into a structured classroom environment. Together, the mangrove prototypes, the COVID-19 community health materials, and the Maya STEM Plus textbooks laid the empirical and methodological foundation for the concepts and approaches later formalized in the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen, 2025) and the *Ethnotranslation Model* (Thigpen, 2026).

The scientific content used in both the 4th and 5th grade books was developed under the author's editorial supervision by biologists primarily from the Global South as part of the *Ethnotranslation Process* which was still being developed (Thigpen & Poot Cahun 2022; & Poot Cahun & Thigpen 2023). Each contributor worked with aquatic, marine or terrestrial species they actively studied in their home countries, ensuring ecological and taxonomic accuracy from the perspective of practicing conservation scientists who worked with and respected Creole and Indigenous communities. These collaborators were not from the Yucatán Peninsula or from Maya communities. They did not attempt to frame their material through Maya cultural lenses. Instead, their role was to provide clear and accessible scientific foundations described in the *Ethnotranslation Frameworks* and emphasizing *biocultural constants* (Thigpen, 2025; Thigpen, 2026). The final steps of ethnotranslation, adapting these materials linguistically, epistemologically and pedagogically for Maya primary school students were carried out by Hilario Poot Cahun, a maya educator, whose expertise ensured that each chapter became not only comprehensible in Yucatec Maya but resonant with local epistemologies and classroom realities.

Knowledge Provenance and Chapter Origins

The Maya-language STEM Plus textbooks were not developed from a single research project, institution, disciplinary tradition, or geographic region. Rather, they assembled scientific content contributed by researchers, conservation practitioners, Indigenous educators, and community knowledge keepers working within the same ecoregions or species ranges. The geographic, disciplinary, and linguistic provenance of these materials is summarized in Table 4. Importantly, none of the content was originally developed for Maya-speaking students in Quintana Roo. At the time these materials were being created, the next phase of implementation was expected to begin in either Belize or Honduras, where many of the original Indigenous, Kriol and governmental partnerships had been established and where the coastal focus of the mangrove and fisheries materials was most immediately applicable. Expansion into Maya-speaking communities was always part of the broader regional vision, but the COVID-19[4] pandemic altered the project's developmental pathway. As opportunities for

[4] Concerns about introducing COVID-19 into partner communities influenced implementation timelines. The author participated in the AstraZeneca COVID-19 vaccine trial and was assigned to the treatment group prior to resuming field-based activities.

implementation re-emerged, collaborations with Maya educators, Indigenous primary schools, UIMQROO, and SEQ created an unexpected beginning for the next phase of the project, resulting in the first large-scale implementation occurring in Maya-language schools in Quintana Roo.

The resulting textbooks therefore represent a convergence of multiple knowledge networks whose original audiences often differed substantially from the Maya primary school students who later participated in the pilot. The 4th grade volume incorporated contributions from researchers working on mangroves, primates, sea turtles, manatees, invasive species, birds, wetlands, and coastal ecosystems. The scientific contributors, knowledge origins, and conservation contexts represented in the 4th-grade textbook are summarized in **Table 2**. The 5th grade volume expanded this network further by incorporating content derived from systematic biology, fisheries science, invasive species management, ornithology, coral reef conservation, and Maya language education. The geographic origins, conservation contexts, and linguistic pathways associated with the 5th-grade textbook are summarized in Table 3.

Contributors included scientists from institutions such as the Smithsonian National Museum of Natural History, Sirenian International, The Gulf and Caribbean Fisheries Institute, ECOSUR, the University of Panamá, the Belize Fisheries Department, *Stichting Nationale Parken* Bonaire, Belize Bird Rescue, *Universidad Autónoma Metropolitana*, UIMQROO, SEQ, and numerous conservation organizations throughout the Caribbean and Abiayala.

Many chapters originated from ongoing conservation programs and scientific investigations located far from the Yucatán Peninsula. The primate materials, for example, emerged from broader Panamanian primate conservation efforts and were subsequently ethnotranslated to focus on species more relevant to Maya students. The invasive lionfish materials were originally associated with Belizean fisheries and conservation initiatives. Coral and reef chapters reflected expertise developed through work on Raja Ampat coral reefs, sea turtles, fisheries, and coastal ecosystems. During adaptation, species selections, examples, illustrations, and linguistic framing were modified to increase cultural relevance for Maya students while preserving scientific rigor.

Visual representation emerged as an important consideration throughout both the multilingual mangrove prototype phase and the subsequent Maya-language STEM Plus curriculum. While efforts were made to incorporate locally relevant photographs, illustrations, species, landscapes, and cultural references, the degree of visual localization varied among editions. Much of the project's photography, artwork, scientific expertise, design work, and editorial labor were donated, and financial constraints limited the ability to commission extensive community-specific visual materials for every linguistic group and educational context.

At the same time, not all imagery was intended to be locally specific. The project sought to balance place-based relevance with broader ecological literacy by including images that illustrated species, ecological processes, conservation challenges, and environmental relationships extending beyond individual communities and national boundaries. This approach reflected the project's broader emphasis on ecological connectivity, knowledge portability, and shared stewardship across ecoregions.

Future iterations would benefit from greater investment in community-generated visual archives, locally commissioned artwork, and regionally specific photography. Such additions would further strengthen cultural representation while maintaining the broader ecological perspective that underlies the STEM Plus framework.

The significance of this process extends beyond curriculum development. It demonstrates that scientific knowledge generated within distinct institutional, disciplinary, and geographic contexts can be reorganized through ethnotranslation into a coherent educational framework capable of functioning in a new linguistic and cultural environment. To further illustrate these pathways of knowledge movement and adaptation, Table 4 synthesizes the geographic, disciplinary, and linguistic provenance of the major STEM Plus themes incorporated into the Maya pilot. The Maya pilot therefore evaluated not only educational materials but also the interoperability of culturally significant scientific knowledge originating across multiple ecological, cultural, disciplinary, and social settings.

Importantly, the contributors represented in Tables 2–5 were not merely content providers; they were also stakeholders in the broader success of the multilingual mangrove prototypes and the Maya STEM Plus project. Tables 2–4 summarize the scientific and educational contributors whose work informed the curriculum, while Table 5 identifies the Indigenous and Creole coauthors whose linguistic, cultural, and ecological expertise shaped the multilingual prototype series from which many of these methods emerged. These stakeholders included conservation scientists, Indigenous and Creole educators, ethnotranslators, language activists, community knowledge keepers, conservation practitioners, and a wider network of photographers, illustrators, designers, and other collaborators who donated their time, expertise, images, artwork, and creative skills in support of the project's educational and conservation goals. Although they worked in different countries, institutions, disciplines, and linguistic communities, many were engaged with conservation challenges affecting the same ecoregions, migratory species, fisheries, forests, and coastal ecosystems represented within the curriculum. Sea turtles move across the Caribbean Basin, mangrove ecosystems span national boundaries, invasive species spread through interconnected watersheds, and many terrestrial species occupy ranges extending across multiple countries. Consequently, the successful adaptation of these materials within Maya-speaking communities provided an opportunity to evaluate whether scientific and ecological knowledge developed in one cultural, linguistic, geographic, or institutional context could be effectively communicated, understood, and applied in another.

Many contributors were also committed to broader goals of conservation education, community engagement, language revitalization, and linguistic inclusion. Notably, many of these stakeholders were not trained linguists, language scholars, or specialists in Indigenous language revitalization. Rather, they were biologists, ecologists, fisheries scientists, conservation practitioners, wildlife rehabilitators, educators, and community leaders whose primary professional interests centered on biodiversity conservation and environmental stewardship. For these stakeholders, the Maya pilot represented not simply a local educational intervention; it served as a test of whether community-authored, multilingual educational materials could successfully bridge scientific research, Indigenous and

Creole knowledge systems, and local ecological stewardship. In this sense, the project's outcomes carried implications not only for Maya-speaking students in Quintana Roo, but also for conservation practitioners, educators, language activists, artists, communicators, and researchers working throughout the greater Caribbean Basin and Abiayala who face similar challenges of communicating ecological knowledge across linguistic, cultural, and political boundaries. In this respect, the Maya pilot served as a shared proof-of-concept for a diverse network of stakeholders whose conservation, educational, and linguistic goals extended far beyond Quintana Roo.

Additionally, attention was paid to how curriculum design itself evolved across linguistic groups. The prototype template originally developed in Honduras using content derived from "*Lilian di Labsta*", the first authors first attempt to create biocultural materials in Belize (Thigpen, 2025), was adapted in distinctive ways, some versions emphasized spiritual framing, others conversational tone, and still others rigorous terminological consensus. These divergences are central to understanding the *Ethnotranslation Model* not only as a linguistic method, but as a vehicle for curricular transformation.

Throughout this paper, I refer to ethnotranslation as the process of adapting ecological content into local languages in ways that reflect culturally specific epistemologies, worldviews, and narrative forms. This stands in contrast to conventional translation, which often assumes linguistic equivalence without regard for epistemic or pedagogical difference. (Thigpen, 2026) Likewise, the *Hybridization Hypothesis* describes the coexistence of distinct ecological knowledge systems, as Indigenous cosmologies and Western ecological science within a shared curricular frame, **without** requiring assimilation or synthesis into a Western framework (Thigpen, 2025).

Results

The analysis of multilingual ethnotestimonials and classroom implementations revealed consistent patterns across linguistic and cultural contexts. These patterns extend beyond individual narratives, pointing to shared mechanisms through which language, ecological knowledge, and epistemologies interact. Three primary themes emerged: (1) the alignment of local ecological knowledge with scientific concepts, (2) the role of language in shaping student engagement and identity, and (3) the emergence of shared ecological understandings across geographically and linguistically distinct communities [biocultural constants]. Together, these findings demonstrate that multilingual, community-authored materials do not merely translate scientific content but restructure how ecological knowledge is recognized, organized, and transmitted.

a. Language as Ecological Memory

Many contributors describe their mother tongues as the primary means by which ecological knowledge is transmitted. References to moon phases, bird calls and fishing practices appear as culturally embedded knowledge (Thigpen, 2026). Language is portrayed not merely as a tool, but as the medium through which people come to know their local ecosystems (Thigpen, 2025).

b. Educational Alienation and Cultural Loss

These *Ethnotestimonials* frequently critique national education systems for ignoring Indigenous languages and environmental realities. When schooling displaces local cosmologies, children become linguistically

and ecologically disoriented. This concern is echoed across all communities represented.

c. Curriculum as Cultural Revitalization
Several authors express hope that the mangrove textbooks can serve as bridges between traditional knowledge and formal education. By including Indigenous language and worldview in science education, these materials help affirm identity and empower youth as stewards of their territories (Poot Cahun, 2025; Thigpen, 2025).

These aspirations are also consistent with broader Indigenous scholarship on Maya language revitalization. Cru (2016), drawing on the reflections of young Maya scholars and language activists, describes an evolution from viewing language revitalization primarily in terms of linguistic purity toward a more functional understanding of Maya. As Yazmin Novelo observes, *jach Maya* is ultimately "that which is understood, which allows communication." Although developed independently, MCB's *STEM Plus Framework* reflects a complementary perspective by seeking to demonstrate that Indigenous languages are capable not only of communication, but also of supporting scientific inquiry, environmental stewardship, higher education, and knowledge generation. Together, these perspectives suggest that the long-term vitality of Indigenous languages depends not only on their preservation as repositories of cultural heritage, but also on their continued use in addressing contemporary educational, environmental, and societal challenges.

This perspective is also consistent with Sima Lozano, Perales Escudero, and Be Ramírez (2013), who argue that language policies should seek to increase not only the prestige of the Maya language itself but also the prestige of its speakers. In many respects, the community-authored educational model presented here contributes to that objective by recognizing Indigenous educators, students, community knowledge keepers, and language specialists as coauthors, ethnotranslators, researchers, and knowledge generators. By positioning Maya as a language of scientific inquiry, environmental stewardship, higher education, and community leadership, the project seeks to strengthen the status and legitimacy of both the language and its speakers while recognizing Indigenous languages as active sites of knowledge generation as well as knowledge transmission (Thigpen, 2026).

These findings also emerged through structural divergence across editions. In some languages, lessons are highly formalized, while in others they take the form of storytelling or metaphor. Even though the ecological realities remained constant, the means of engagement and emotional texture varied dramatically. These variations reflect the linguistic, epistemic and pedagogical traditions of each community and demonstrate the centrality of cultural form in determining educational impact.

These divergences extended beyond narrative tone and pedagogical framing into the technical realities of multilingual publishing itself. While some editions emphasized storytelling, spiritual reflection, or ecological translanguaging, others introduced challenges associated with entirely different orthographic systems. The Burmese edition, for example, required substantial adaptation to accommodate non-Latin script formatting, rendering behavior, and localized typographic conventions. Community collaborators, including Ne Nan Nandar Nwe of Myanmar, became essential not only as ethnotranslators but also as technical and publishing mediators who helped ensure that the educational materials functioned coherently within local linguistic

infrastructures.

These experiences demonstrated that multilingual conservation education requires not only linguistic and ecological adaptation, but also technological flexibility capable of supporting diverse writing systems and modes of textual organization.

Polyphonic Reflections

These quotations from the Introductions illustrate the diversity and convergence of perspectives:

- **Wayuu:** "*My reading was nothing but the song of birds, the tracks of animals in the sand, the morning revelation of night dreams*." ~Maria Josefa Epieyuu (Thigpen etal. 2018)

- **Yucatec Maya:** "*This project provides Maya students an opportunity to learn in their own language, through which they better understand and appreciate science, and affirm their cultural identity*." ~Felicita Cantun (Thigpen and Poot Cahun; 2018)

- **Mopán Maya:** "*This mangrove book in our Mopán language will promote appreciation of both language and the deep meaning of mangroves to our coastal ecosystems*." ~Midonio Cal (Thigpen etal., 2021)

- **Q'eqchi' Maya:** "*Indigenous wisdom is the foundation for teaching the importance of protecting Mother Nature and the Caribbean Sea*." ~Edgar Fernando Pop Tiul (Thigpen and Pop Tuil; 2020)

- **Garifuna:** "*The sea is the heritage of many peoples. It is our responsibility to protect it for our children's children*." ~Cheryl L. Noralez (Thigpen and Bermudez; 2018)

- **Miskitu:** "*Our ancestors used natural resources wisely and sustainably. We must return to those ways*." ~Scott Wood Ronas (Thigpen and Ronas; 2019)

- **Ulwa:** *Our mother tongue is what identifies us as a united people moving toward a better future*. ~Leonzo Knight Julian (Thigpen and Julian; 2021)

- **Bahasa:** "*My Earth, Your Earth, His Earth is Our Earth*." ~M. Irham Saputra (Thigpen etal., 2020)

- **Burmese**: "*These books are designed to blend local fishers' knowledge and their local languages with the language and concepts of science so they are better equipped to discuss these issues in the languages they use*." ~Ne Nan Nandar Nwe (Thigpen and Nwe, in press.)

These reflections are poetic, affective, and epistemological. They connect the act of speaking with the act of knowing and caring for place. Their inclusion in the textbooks marks a rebalancing of authorship and authority.

Although many participants were from either Indigenous or Creole communities, these educational interventions also sparked interest among dominant-language speakers in adjacent communities. These findings point to the value of localized, bioregional science education that transcends ethnolinguistic lines and international borders; and reinforces shared environmental responsibilities. Remarkably, this may represent the first documented instance in which dominant-language speakers openly acknowledged that educational materials developed for Indigenous and Creole communities were superior to those used in their own classrooms.

Linguistic and Cultural Distinctions Across Prototypes

Although all nine prototypes are based on a shared ecological curriculum, each one bears the imprint of its respective linguistic, cultural, and interpretive context. The Garifuna edition is rooted in maritime communalism and intergenerational responsibility, while the Q'eqchi' Maya version presents mangroves as sacred ancestral landscapes, blending spiritual and ecological metaphors. The Miskitu edition echoes a didactic tone, grounded in oral traditions of sustainability. The Ulwa book places emphasis on language reclamation and the emotional weight of remembering ancestors.

Meanwhile, the Wayuu prototype stands out for its poetic, metaphor-rich expression and inclusion of a photo of the contributor, Maria Josefa Epieyuu, visually reaffirming the personal voice of the testimony. The Yucatec Maya version reflects academic collaboration, where university translation workshops at UIMQROO and consensus lexicons enabled structured neologism creation. The Mopán edition was highly integrated with school partnerships, reinforcing its role in language preservation and curriculum testing. Finally, the Belizean Kriol book featured the most adaptive ethnotranslation, utilizing ecological translanguaging, neologisms, and ecological transknowledging to reach students in their home linguistic register.

These distinctions underscore that there is no singular cultural or linguistic instantiation of Indigenous ecological knowledge translation. The methodological portability observed across ecoregions and species ranges was made possible by *Relational Learning* grounded in long-term engagement with Belizean Kriol, Maya, Garifuna, and Mestizo fisher folk, whose everyday interactions with mangrove and coastal ecosystems informed design choices that remained effective when later applied across diverse linguistic and ecological contexts. Rather than producing uniform outputs, each testimony reflects a distinct form of curriculum sovereignty rooted in local cosmologies, pedagogical traditions, and sociolinguistic landscapes.

At the same time, the *Ethnotranslation Model* outlines a replicable, phased methodology in which the first phase establishes the relational, ethical, and epistemic conditions necessary for ecological content to be rearticulated. It is this initial phase grounded in *Relational Learning* that creates the environment enabling content to be rearticulated in diverse languages and cultural registers while preserving a consistent scientific framework (Thigpen, 2026). Together, these localized adaptations form a pluriversal archive of how science education can be reimagined from the ground up, demonstrating both structural flexibility and epistemic integrity within the STEM Plus model.

Linguistic and Curricular Distinctions Across Prototypes

While all prototypes share a common ecological foundation rooted in mangrove ecology and conservation biology, each localized edition diverges meaningfully in how that content is translated, framed, and delivered. These divergences are not superficial. They reflect deep commitments to community-defined values, linguistic integrity, and epistemic relevance.

The original Spanish/English prototype, co-developed in Honduras by Grazzia Matamoros Erazo, José Antonio Romero Durón, and the project leader, served as the foundational template for the series. It established the dual-language modular

structure and visual-textual pairing. This template was first applied in the Belizean Kriol prototype, which quickly demonstrated the adaptability of the original model.

Each subsequent edition adapted and sometimes fundamentally reimagined the English / Spanish mangrove prototype to suit local epistemologies, linguistic registers, and pedagogical expectations while maintaining a recognizable ecological curriculum core grounded in shared biocultural constants.

English / Spanish: Serving as the foundational source text for many subsequent adaptations, the bilingual English-Spanish edition was designed to bridge scientific terminology and conservation concepts across linguistic communities throughout the greater Caribbean Basin. Drawing upon both marine biology and social scientific approaches, it explicitly sought to integrate local fishers' ecological knowledge with the language and concepts of science. The edition introduced many of the pedagogical structures, ecological themes, and neologism-development challenges that would later be adapted and expanded through subsequent ethnotranslations. Rather than functioning solely as a translation, it served as a foundational reference point from which later Indigenous and Creole language editions diverged while maintaining a shared ecological foundation (Thigpen, etal 2018).

Although all editions shared a common ecological architecture rooted in mangrove ecology, fisheries connectivity, and community stewardship, each community adapted the material according to its own linguistic conventions, cultural priorities, educational traditions, and knowledge systems.

Belizean Kriol: This edition uses ecological translanguaging[5] (Thigpen, 2025), neologisms, borrowed words written using the phonetic structure of Belizean Kriol and ecological translanguaging to mirror students' home speech. Its tone is intimate, rhythmic, and conversational intentionally designed to sound as if it *belongs* around a kitchen table in Pickstock or on the Caye. This aligns with García and Kleyn's (2016) observation that translanguaging can amplify student engagement when instructional language reflects authentic communicative practice. (Thigpen etal 2017)

Wayuu: Opened by an oral-style testimony from an elder woman who never learned to read or write. This version critiques disruptive effects of dominant language literacy on Indigenous knowledge transmission. It invokes memory, metaphor, and intergenerational knowledge in place of formal instruction. (Thigpen etal. 2018)

Garifuna: Developed in collaboration with Garifuna educators, language activists, and cultural organizations in Belize, Honduras, Guatemala, and the United States, this edition explicitly links mangrove conservation to Garifuna cultural survival, food security, and maritime heritage. Rather than treating conservation as a purely scientific subject, it frames the sea as both an ecological and cultural inheritance. The edition combines

[5] Thigpen (2025) defines Ecological Translanguaging as the intentional use of multiple languages in biology education to support ecological understanding across linguistic, cultural, and epistemological boundaries. Drawing on the tradition of translanguaging as both a sociolinguistic and ecological practice (Fine, Caitlin G.2018; García & Kleyn, 2016; Lewis, Jones, & Baker, 2012; Li Wei, 2018), and informed by language ecology theory (Haugen, 1972). The term here describes how multilingual learners mobilize their full linguistic repertoire to engage with both Indigenous or Creole and Western ecological knowledge systems.

newly created scientific terminology, community language planning, and reflections on intergenerational stewardship, while emphasizing the preservation of both ecosystems and the Garifuna language itself. The translation process relied heavily on Garifuna linguistic expertise and became an early demonstration of how conservation education could simultaneously support language revitalization and ecological literacy. (Thigpen & Bermúdez, 2018)

Yucatec Maya: This version emerged from translation workshops at UIMQROO and consensus-building among Maya educators and researchers. It uses carefully structured neologisms and became a laboratory for later STEM Plus iterations. (Thigpen and Poot Cahun; 2018)

Miskitu: Written in a more didactic tone, this edition reflects oral teaching traditions and ancestral stewardship practices. Coauthored with educators from the *Centro de Educación Bilingüe Intercultural de la Mosquitia Hondureña* it blends formal instruction with narrative cadence. (Thigpen and Ronas; 2019)

Q'eqchi' Maya: Framed in ancestral spirituality, this edition presents mangroves as sacred landscapes. It combines moral teachings with cosmological references and critiques of extractive logics. (Thigpen and Pop Tuil; 2020)

Ulwa: Developed with Karawala's language committee, the Ulwa edition emphasizes linguistic reclamation and emotional connection to the land. It reflects a community emerging from cultural trauma with renewed purpose. (Thigpen and Julian; 2021)

Bahasa/Burmese (Indonesia/Myanmar): These Southeast Asian prototypes represented the most geographically distant adaptations within the mangrove curriculum lineage. The Indonesian edition contextualized mangrove conservation through regional fauna, marine biodiversity associated with Alor Island, and mangrove regeneration, demonstrating that the ecological framework could be successfully transferred beyond the Caribbean Basin while retaining its core conservation concepts (Thigpen et al., 2020). The Burmese edition further expanded this experiment by demonstrating how multilingual conservation curricula must adapt not only to different languages but also to entirely different writing systems, textual organizations, and technological infrastructures. The Burmese ethnotestimonial emphasized the integration of local fishers' ecological knowledge with scientific language to strengthen community participation in marine conservation. Community collaborators, including Ne Nan Nandar Nwe, became essential not only as ethnotranslators but also as technical mediators capable of adapting the curriculum to function coherently within local typographic systems. Together, these Southeast Asian editions expanded the concept of ethnotranslation beyond language itself, demonstrating that multilingual curriculum sovereignty also depends upon technological accessibility, script inclusivity, and the successful transfer of ecological concepts across distinct biogeographic regions (Thigpen et al., 2020; Thigpen & Nwe, in press).

These distinctions do more than localize vocabulary; they reframe what counts as knowledge, who counts as an author, and how conservation is taught. As such, each book constitutes an act of curricular sovereignty and a contribution to a pluriversal archive of Indigenous, Creole and coastal ecological education.

Table 1. Developmental Lineage of the Multilingual Mangrove Prototype Series and Related STEM Plus Adaptations

Linguistic Community	*Country / Region*	*Developmental Significance*
Belizean Kriol	Belize	Rooted in lessons learned from *Lillian the Lobster* and early multilingual conservation education efforts; foundational influence on later STEM Plus development.
English	Belize	Early conservation education adaptations that facilitated broader regional dissemination.
Spanish	Honduras and wider Mesoamerica	First major cross-linguistic adaptation pathway and foundation for later Indigenous-language adaptations.
Garifuna	Belize / Honduras Guatemala / Nicaragua	Early heritage-language adaptation that helped test community-based ethnotranslation approaches.
Wayuu	Colombia / Venezuela	Early Indigenous-language adaptation demonstrating transferability beyond the Mesoamerican context.
Yucatec Maya	Mexico / Belize	First large-scale classroom implementation and formal evaluation of STEM Plus materials.
Mopán Maya	Belize / Guatemala	Extension of the model into additional Maya-speaking communities.
Q'eqchi' Maya	Belize / Guatemala	Further Indigenous-language adaptation and testing.
Ulwa	Karawala, Nicaragua	Expansion into a distinct linguistic family and cultural tradition.
Miskitu	Nicaragua / Honduras	Adaptation within another Indigenous linguistic and ecological context.
Bahasa Indonesia	Indonesia	Demonstrated transferability beyond the Caribbean Basin and Mesoamerica.
Burmese	Myanmar	Demonstrated applicability across major geographic, cultural, and linguistic boundaries.

Table 1. Developmental Lineage of the Multilingual Mangrove Prototype Series and Related STEM Plus Adaptations. This table summarizes the major linguistic adaptations that contributed to the evolution of the STEM Plus project. Rather than representing simple translations of a common text, each adaptation involved varying degrees of ecological interpretation, cultural contextualization, neologism development, and pedagogical innovation. Collectively, these adaptations provided the experimental foundation from which the Ethnotranslation Model and later Maya-language STEM Plus curriculum emerged.

Table 2. Provenance of Scientific Content in the 4th-Grade Maya STEM Plus Textbook

Chapter	*Author(s)*	*Knowledge Origin*	*Original Context*	*Languages Used Prior to or Alongside Maya*
Scientific Names and Taxonomy	Anna J. Phillips	USA	Smithsonian taxonomy and systematics	English, Spanish, Maya
Maya Orthography	Hilario Poot Cahun	Quintana Roo	Maya language education	Maya
Mangroves	Matamoros, Romero Durón, Thigpen	Honduras / Belize	Mangrove prototype	English, Spanish, Kriol, Maya, Mopán, Garifuna, Q'eqchi'
Sea Turtles	Contuchio, Moreno Munar, Thigpen	Caribbean Basin	Marine conservation education	English, Spanish, Maya
Primates	Gutiérrez, Méndez-Carvajal	Panamá	Primate conservation	Spanish, English, Maya
Manatees	Corona, Castelblanco-Martínez, Brady, Thigpen	Guatemala/ Colombia / USA / Belize	Aquatic mammal conservation	English, Spanish, Maya
Scarlet Macaws	Joyner	Honduras	Community conservation education	English, Spanish, Maya
Invasive Catfish	Schmitter-Soto, Quintana et al.	Belize / Quintana Roo	Belize Fisheries Dept. invasive species management	English, Kriol, Spanish, Maya
Sargassum	Bartlett	UK / Caribbean	Coastal management	English, Spanish, Maya

Table 2. Scientific Contributors, Knowledge

Origins, and Conservation Contexts Represented in the Maya STEM Plus Textbooks. *This table identifies the principal scientific contributors whose work informed the 4th and 5th grade Maya STEM Plus textbooks. The chapters originated from diverse conservation, research, and educational contexts throughout the Caribbean and Mesoamerica and were subsequently adapted through the Ethnotranslation Model for use in Maya-language primary school classrooms.* (Thigpen & Poot Cahun 2022; & Poot Cahun & Thigpen. 2023)

Table 3. Provenance of Scientific Content in the 5th-Grade Maya STEM Plus Textbook

Chapter	*Author(s)*	*Knowledge Origin*	*Original Context*	*Languages Used Prior to or Alongside Maya*
Scientific Names and Taxonomy	Anna J. Phillips	USA	Smithsonian parasitic taxonomy and systematics	English, Spanish, Maya
Maya Orthography	Hilario Poot Cahun	Quintana Roo	Maya language education	Maya
Lionfish	R. Leroy Creswell	Caribbean Basin	Invasive species management	English, Spanish, Maya
Queen Conch	Monique Grol	Bonaire	Fisheries and conservation	English, Dutch, Papiamentu, Spanish, Maya
Coral Reefs	Phil Dustan	Raja Ampat	Coral reef ecology	English, Spanish, Maya
Amazona Parrots	Nikki Buxton	Belize	Wildlife rehabilitation	English, Spanish, Maya
Spider Monkey	Braulio Pinacho Guendulain,	Tabasco, Mexico	Biodiversity and primate conservation	Spanish, Maya

Table 3. Geographic and Linguistic Pathways Through Which Scientific Knowledge Entered the Maya STEM Plus Curriculum. *This table traces the geographic origins, original conservation contexts, and linguistic adaptation pathways associated with major themes incorporated into the Maya STEM Plus textbooks. The table illustrates how knowledge developed across multiple countries, disciplines, and linguistic traditions was adapted and integrated into a common Maya-language educational framework.*

Table 4. Geographic and Linguistic Provenance of Major STEM Plus Themes Incorporated into the Maya Pilot

Chapter / Theme	*Primary Contributor(s)*	*Knowledge Origin*	*Original Context*	*Linguistic Pathways and Adaptations*
Scientific Taxonomy	Anna J. Phillips	United States	Systematics and biological classification	All Mangrove Prototype Languages
Maya Orthography	Hilario Poot Cahun	Quintana Roo, Mexico	Maya language revitalization and literacy	Maya → Spanish → English →
Mangroves	Grazzia Matamoros, José A. Romero Durón, Robby Thigpen	Honduras / Belize	Original mangrove prototype and coastal conservation education	English → Spanish → Kriol → Maya → additional adaptations
Sea Turtles	Jenna Contuchio, Alvaro Andrés Moreno Munar, Robby Thigpen	Global	Marine conservation and environmental education	English → Spanish → Maya
Primates	Karol Gutiérrez, Pedro G. Méndez-Carvajal	Panamá	Neotropical primate conservation	Spanish → Maya
Manatees	Fabiola Corona, Nataly Castelblanco-Martínez, Beth Brady	Guatemala / Colombia / Belize / United States	Aquatic mammal conservation and environmental education	English → Spanish → Maya
Scarlet Macaws	LoraKim Joyner	Honduras	Community-based parrot conservation	Spanish → Maya

Invasive Catfish (*Pterygoplichthys* spp.)	Juan J. Schmitter-Soto et al.	Belize / Quintana Roo	Fisheries science and invasive species management	English / Kriol → Spanish → Maya
Sargassum	Debbie Bartlett	United Kingdom / Caribbean Basin	Coastal and marine environmental management	English → Spanish → Maya
Lionfish (*Pterois volitans, P. miles*)	R. Leroy Creswell	Wider Caribbean	Invasive species management and fisheries education	English → Spanish → Maya
Queen Conch (*Lobatus gigas*)	Monique Grol	Bonaire / Caribbean Basin	Fisheries management and marine conservation	English / Dutch / Papiamentu → Spanish → Maya
Coral Reefs	Phil Dustan	Raja Ampat, Indonesia	Coral reef ecology and conservation science	English → Spanish → Maya
Amazona Parrots (*Amazona* spp.)	Nikki Buxton	Belize	Wildlife rehabilitation and conservation education	English → Kriol → Spanish → Maya
Spider Monkey (*Ateles geoffroyi*)	Braulio Pinacho Guendulain,	México	University level primate ecology	Spanish → Maya

Table 4 illustrates that the scientific content incorporated into the Maya pilot originated from multiple countries, conservation programs, and disciplinary traditions. In most cases, these materials were developed for audiences other than Maya-speaking students and subsequently adapted through the Ethnotranslation Model and STEM Plus framework. The table demonstrates that scientific knowledge generated across diverse ecological and linguistic contexts can be reorganized into a coherent educational system without requiring a common geographic origin, disciplinary background, or language of initial development.

Table 5. Indigenous and Creole Ethnotranslators, Community Coauthors, and Linguistic Communities Represented in the Multilingual Mangrove Prototype Series

Language / Community	*Coauthor(s)*	*Community / Affiliation*	*Country / Region*	*Role in Project*
Belizean Kriol	Yaricel Castillo, Celeste Castillo, Zaida Castillo	Belizean Kriol fishing community	Belize	Ethnotranslators and community coauthors
Garifuna	Cheryl Noralez, & Elmer Mauricio Enríquez Bermúdez	Garifuna language and cultural organizations	Belize / Guatemala / USA	Ethnotranslation, terminology development, cultural framing
Q'eqchi' Maya	Edgar Fernando Pop Tiul	Q'eqchi' Maya educator and conservation advocate	Guatemala	Ethnotranslation and ecological interpretation
Mopán Maya	Midonio Cal, Richard Peck & Juan Ico	Mopán Maya educator	Belize	Ethnotranslation and educational adaptation
Yucatec Maya	Felicita Cantun & Hilario Poot Cahun	Maya educators	Mexico / Belize	Ethnotranslation and curriculum adaptation
Miskitu	Scott Wood Ronas	Intercultural bilingual education leader	Honduras	Ethnotranslation and educational adaptation
Ulwa	Leonzo Knight Julian	Ulwa Language Committee	Nicaragua	Ethnotranslation and language revitalization
Wayuu	Maria Josefa Epieyuu & Aminta Peláez Guariyu	Wayuu elder and knowledge keeper	Colombia/Venezuela	Ethnotestimonial contributor
Bahasa Indonesia	M. Irham Saputra & Suriyono	Community conservation educator	Indonesia	Adaptation and contextualization
Burmese	Ne Nan Nandar Nwe	Marine conservation educator	Myanmar	Ethnotranslation and script adaptation

Table 5 identifies the Indigenous and Creole coauthors who contributed to the multilingual mangrove prototype series and the linguistic communities they represented. These collaborators served not merely as translators, but as ethnotranslators, community knowledge holders, educators, language activists, and cultural mediators whose

contributions shaped the linguistic, ecological, and pedagogical character of each edition. Their work informed the development of the Ethnotranslation Model, contributed to the observations that later informed the Hybridization Hypothesis of Ecological Knowledge Systems, and provided the community-authored foundation from which the Maya-language STEM Plus curriculum ultimately emerged. As stakeholders in the broader project, these coauthors helped demonstrate how conservation education can be adapted across diverse linguistic, cultural, and ecological contexts while maintaining both scientific rigor and local relevance .

Discussion and Framework Integration

The *Ethnotestimonials* analyzed here function as both curricular content and declarations of epistemic agency. They embody the principles of the *Ethnotranslation Model* developed in earlier research (Thigpen, 2025, 2026), treating language not as a neutral vessel for conveying information but as a living epistemology through which knowledge is produced, interpreted, and transmitted. Accordingly, ethnotranslation is understood not simply as linguistic transfer but as a process of ethical engagement, reciprocal recognition, and collaborative knowledge generation.

Although this work is informed by previous publications that formalized the *Hybridization Hypothesis of Ecological Knowledge Systems* and the *Ethnotranslation Model*, the educational prototypes examined here predate those theoretical frameworks. The theories were subsequently developed to explain patterns that had already emerged through the collaborative design, implementation, and evaluation of the educational materials. Thus, practice preceded theory, with the prototypes providing the empirical foundation from which the conceptual frameworks were derived. In fact, these community-authored reflections played a formative role in shaping both the *Ethnotranslation Model* and *Hybridization Hypothesis* frameworks. They served as foundational empirical touchpoints that informed and inspired the development of those subsequent models. The prototypes analyzed here thus serve as grounded examples of these frameworks in action, providing community-authored insight into how linguistic and ecological knowledge can be jointly revitalized through participatory curriculum design.

What emerged was a curriculum that braided three layers of expertise: Global South scientific authorship, editorial integration, and localized ethnotranslation (Thigpen & Poot Cahun, 2022; Poot Cahun & Thigpen 2023). The biologists provided regionally grounded ecological content often drawn from species and ecosystems far from the Yucatán Peninsula (Thigpen, 2025; Thigpen, 2026). These chapters, while scientifically rigorous and developed within culturally relevant conservation contexts, were not initially written with Maya students in mind. That act of Maya cultural alignment came later, through a careful process of the second phase of the *Ethnotranslation Model* and then finalized by Hilario Poot Cahun. This collaborative layering allowed the curriculum to maintain scientific rigor while also achieving local relevance, an approach that proved both effective and replicable. (Poot Cahun, 2025; Thigpen 2026)

The Southeast Asia adaptation further demonstrated that ethnotranslation operates not only at the conceptual and linguistic levels, but also within the technological infrastructures that enable polylingual publishing. The Burmese edition revealed that script rendering, typography, and digital formatting are themselves sites of inclusion or exclusion within global educational systems. In these contexts, community collaborators functioned simultaneously as translators, cultural interpreters, and technical mediators. This expanded the project's understanding of curriculum sovereignty by illustrating that linguistic

accessibility also depends upon the capacity of publishing systems to accommodate diverse orthographies, writing systems, and textual structures.

The Maya-language STEM Plus textbooks also provided important evidence for the portability of the methods that would later be formalized in the *Hybridization Hypothesis* and the *Ethnotranslation Model*. The fact that content written by biologists from the Global South, originally framed for entirely different countries and contexts, could be successfully integrated into a Maya-language curriculum underscores the robustness of the underlying approach. By emphasizing ecological specificity, layered authorship, and culturally grounded ethnotranslation, the methodology proved adaptable across linguistic, geographic, and educational boundaries. The 4th and 5th grade materials thus served as a proving ground for what would later become codified as a replicable, multilingual framework for biocultural education.

The Maya textbooks therefore became more than educational materials. They became a test of whether scientific knowledge generated by researchers working in entirely different ecological, linguistic, and institutional contexts could be reorganized through ethnotranslation into a coherent Indigenous-language curriculum. The positive outcomes reported by Poot Cahun (2025) suggest that such reorganization is not only possible, but can produce educational materials that are simultaneously scientifically rigorous, epistemically robust, culturally relevant, and linguistically accessible.

These findings also suggest that the primary unit of replication within this system is not language itself, but rather an underlying ecological curriculum core. Across the multilingual mangrove prototypes and subsequent Maya-language adaptations, linguistic forms, cultural examples, illustrations, narrative structures, pedagogical strategies, and epistemological perspectives varied substantially, while core ecological relationships, conservation concepts, and educational objectives remained recognizable and transferable across communities. The success of the Maya pilot therefore provides evidence that a shared ecological curriculum can be rearticulated through ethnotranslation into multiple linguistic and cultural contexts without requiring the creation of entirely new ecological frameworks for each community. Taken together, these findings suggest that the project is most accurately understood not as a stand-alone language revitalization initiative, conservation education program, or curriculum intervention, but as a *polylingual*[6], multi-stakeholder process in which scientific, cultural, and ecological knowledge was co-developed, adapted, and transmitted through the dynamic interaction of multiple linguistic communities.

An additional implication of this work has received relatively little attention. Belize serves as the first national-scale proof of concept for Thigpen's *Polylingual Education Model*. Within a single country, a shared ecological curriculum was successfully ethnotranslated across every major Indigenous and Creole linguistic community

[6] In the present study, the term *polylingual* refers not simply to the presence of multiple languages, but to an educational process in which knowledge is collaboratively generated, adapted, and circulated through the dynamic interaction of multiple linguistic communities. Unlike conventional multilingual approaches, which often treat languages as parallel or independent systems, a *polylingual* approach emphasizes the reciprocal movement of ideas, scientific concepts, and cultural knowledge across languages through collaborative educational practice.

while maintaining scientific coherence and allowing each community to adapt the curriculum according to its own language, epistemology, and educational traditions. Collectively, the multilingual prototype series includes educational materials developed for Belizean Kriol, Yucatec Maya, Mopán Maya, Q'eqchi' Maya, and Garifuna, representing every major Indigenous and Creole linguistic community in Belize. To our knowledge, this may represent the first documented example of a multilingual nation in which every major Indigenous and Creole language community has access to at least one community-authored environmental science text in its own language. Although these materials were originally developed as conservation education prototypes rather than components of a coordinated national curriculum, they demonstrate that comprehensive multilingual science education across an entire nation's Indigenous and Creole language communities is technically achievable rather than merely aspirational.

The developmental history presented here also highlights a recurring challenge for *polylingual*, community-coauthored, and transdisciplinary initiatives. Projects that emerge simultaneously from conservation practice, Indigenous and Creole language collaboration, scientific communication, and curriculum development often resist easy classification within conventional academic categories. As a result, their broader developmental histories, stakeholder networks, and methodological contributions may be overlooked when interpreted primarily through the lens of a single discipline, institution, or educational framework. The *polylingual* mangrove prototypes examined here illustrate how knowledge can emerge through interactions among multiple linguistic communities, conservation practitioners, educators, and knowledge holders operating across diverse ecological and cultural contexts.

Viewed collectively, the multilingual mangrove prototypes, the Maya-language *STEM Plus* prototype textbooks, the *Ethnotranslation Model*, the *Hybridization Hypothesis of Ecological Knowledge Systems*, and the classroom findings reported by Poot Cahun (2025) should not be understood as independent projects. Rather, they represent successive stages within a single biocultural research ecosystem. The mangrove prototypes provided the initial experimental space in which multilingual curriculum design, community coauthorship, and ecological translanguaging were explored. These experiences informed the development of the *Ethnotranslation Model* and contributed to the observations that later informed the *Hybridization Hypothesis*. The resulting methods were subsequently applied within MCB's Maya-language *STEM Plus* project, where they were subjected to classroom-based evaluation in Indigenous primary schools. Together, these works illustrate an iterative process in which curriculum development, theory building, and educational practice informed one another through cycles of observation, adaptation, and refinement.

The decision to credit each Indigenous ethnotranslator as a coauthor on their book covers and in academic citations was central to ensuring local ownership of the materials. This practice acknowledges their expertise not only in language, but in ecological knowledge, epistemology, and cultural framing. It also affirms curriculum sovereignty by grounding the materials in relationships of mutual authorship and respect. In doing so, the mangrove prototypes became tools of both education and empowerment rooted in community voice and formally recognized as such.

The reciprocal nature of these collaborations was recognized early in the Maya Project's development. After reviewing materials associated with the multilingual mangrove prototypes, Glen Aikenhead Ph.D, a pioneering scholar of Indigenous and cross-cultural science education, observed: "You also played the role of a teacher who learns from his students – *tuakana* as the Māori would say." (Personal communication, August 5, 2020). Although made prior to the formal articulation of *Relational Learning* (Thigpen, 2026), the *Ethnotranslation Model* (Thigpen, 2026), and the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen, 2025), this observation anticipated a central feature of the project: the understanding that meaningful curriculum development emerges through dialogue, reciprocity, and mutual learning among scientists, educators, community knowledge holders, and linguistic experts. In many respects, this process parallels the Maya concept of *Tsikbal* (Castillo Cocom et al., 2015) in which knowledge is generated and refined through conversation, dialogue, and collective reflection rather than transmitted unidirectionally from expert to learner.

Hilario Poot Cahun's thesis represented not only an evaluation of MCB's Maya-language *STEM Plus* textbooks but also the first opportunity to apply, in a sustained classroom setting, many of the curricular strategies developed through the mangrove prototypes. In this sense, his work formed a critical link in the project's progression from experimental prototypes to validated, community-relevant educational tools.

The success of these curriculum strategies was later affirmed by Hilario Poot Cahun's master's thesis, which evaluated the impact of the 4th and 5th grade *STEM Plus* textbooks in Maya-language classrooms in Quintana Roo. His findings demonstrated that students not only retained more scientific content but also expressed a deeper sense of cultural identity and ecological responsibility when materials were delivered in their own language using culturally resonant metaphors. These results lend empirical support to the claim that ethnotestimonials and hybridized curriculum design can enhance both educational outcomes and community engagement. (Poot Cahun, 2025)

Moreover, this model affirms curriculum sovereignty: the right of communities to shape what counts as knowledge and how that knowledge is transmitted. The result is not a universal textbook, but a pluriversal one, grounded in multiple epistemologies that converge in their concern for ecological stewardship.

Operationalizing the Hybridization Hypothesis, Biocultural Constants and Ethnotranslation Models

The multilingual mangrove prototypes presented in this study function not only as curricular interventions but as empirical validation of three theoretical frameworks that would later emerge from this work: the *Hybridization Hypothesis of Ecological Knowledge Systems*, the concept of *Biocultural Constants* (Thigpen, 2025) and the *Ethnotranslation Model* (Thigpen, 2026). Each prototype served as a testbed for operationalizing the core principles of these models, revealing how scientific and Indigenous ecological knowledge systems can be ethically and effectively integrated through participatory design.

The *Hybridization Hypothesis* posits that sustainable science education must emerge from the productive convergence of distinct epistemologies, namely, Western ecological knowledge and place-based ecological worldviews. The mangrove prototypes

embodied this hybrid approach through a layered authorship process. Scientific content was first developed by biologists from the Global South with field expertise, then edited centrally, and finally transformed through localized ethnotranslation by Indigenous and Creole coauthors. These ethnotranslators were instructed to disregard standard translation protocols and instead reframe ecological concepts using the linguistic, metaphorical, and pedagogical structures familiar to their communities. The result was not merely a translation of content but a cultural and epistemic re-articulation of conservation education.

This adaptive process generated nine distinct curricular expressions of the same scientific foundation. For example, the poetic and metaphor-rich Wayuu edition stands in sharp contrast to the didactic tone of the Miskitu version or the ecological translanguaging found in the Belizean Kriol edition. These structural, stylistic, and orthographic divergences were not ancillary, they were central to the hypotheses being tested. They confirmed that the *Hybridization Hypothesis*, when rooted in community authorship and curriculum sovereignty, produces not dilution but innovation. This echoes cognitive studies that show how cultural mental models of nature are shaped by local epistemologies (Bang, Medin, & Atran, 2007), reinforcing the viability of hybrid curricular forms.

The Burmese edition further demonstrated that hybridization can also occur through material and infrastructural adaptation, where script systems, typographic conventions, and localized publishing practices become part of the curriculum design process itself. In this context, multilingual curriculum development required not only epistemological negotiation, but also technological adaptation capable of supporting non-Latin orthographies and culturally specific textual organization.

Simultaneously, the prototypes illustrate the presence of *Biocultural Constants*, recurring ecological themes that transcend linguistic boundaries. Across all nine editions, language emerged as a vessel of ecological memory; mangroves were described not only as habitats but as kin, ancestors, and protectors; and contributors consistently framed ecological stewardship as both moral responsibility and cultural inheritance. These *biocultural constants* help explain how a shared ecological curriculum can remain recognizable across diverse linguistic and cultural contexts while allowing substantial variation in language, narrative structure, and epistemic approach.

In sum, the mangrove prototypes provided a proving ground for the *Hybridization Hypothesis* and the *Ethnotranslation Frameworks*. They transformed theoretical propositions into replicable practice and confirmed that polylingual, community co-authored science education can both preserve cultural knowledge and meet global conservation goals. Their iterative development and subsequent integration into the Maya STEM Plus textbooks affirmed that biocultural education is most impactful when it is co-created, culturally grounded, and structurally flexible.

Authorship and Contributions

This study was conducted through a collaborative process involving Indigenous and Creole ethnotranslators who served as coauthors of the original multilingual mangrove texts and contributed the ethnotestimonials analyzed in this paper. Their contributions include linguistic innovation, ecological interpretation, and narrative authorship grounded in community knowledge systems. These contributions

shaped both the dataset and the analytical insights presented here. The corresponding author led the synthesis, analysis, and manuscript preparation, while all coauthors are recognized for their role in generating the foundational content upon which this study is based.

Data Availability

The multilingual educational materials referenced in this paper are archived in the Archive of the Indigenous Languages of Latin America (AILLA) as part of the Marine Conservation without Borders Collection and are publicly available for download. Additional information about the project is available through Marine Conservation without Borders. At the time of writing, the collection includes multilingual biocultural education and community health materials representing approximately thirty linguistic communities. To our knowledge, it constitutes one of the most linguistically and culturally diverse educational collections housed within AILLA. (Archive of the Indigenous Languages of Latin America, n.d.)

Conclusion

Community-authored multilingual ethnotestimonials and lessons learned from the mangrove prototypes are powerful tools for advancing marine conservation, Indigenous rights, and educational equity. The portability of these methods across species ranges and sociolinguistic contexts reflects their grounding in *Relational Learning* with coastal communities whose livelihoods are inseparable from the ecosystems the curriculum seeks to protect. As poetic declarations and curricular interventions, they make visible the ecological knowledge systems that standard education often renders invisible. The mangrove prototypes produced by Marine Conservation without Borders demonstrate how Indigenous and Creole communities can reclaim authorship over environmental narratives.

The differences between editions were not accidental, they were integral to the learning process. Each prototype tested the boundary between linguistic fidelity and cultural resonance. From the first Spanish / English version to the Ulwa, Wayuu, Miskitu, Kriol and Maya editions, the development process revealed that effective biocultural education must be structurally flexible, allowing form to follow worldview. The Burmese edition further revealed that this flexibility must extend beyond pedagogy and translation into the technological infrastructures of multilingual publishing itself, where script compatibility and orthographic accessibility become integral components of educational inclusion. These findings confirm that pluriversal design is not a theoretical aspiration, it is a pedagogical necessity (Thigpen 2025: Escobar, 2018).

Future research is already underway. In fact, the experiences described in this paper directly gave rise to two subsequent theoretical contributions: the *Hybridization Hypothesis of Ecological Knowledge Systems* and papers on *Ethnotranslation* and *Biocultural Education*. These frameworks were not conceived in abstraction, they were distilled from the practical challenges and insights encountered during the creation of the mangrove prototype.

The methodologies proposed in those papers were first developed and field-tested here. Later, they were combined and further refined during the development of the Maya 4th & 5th grade textbooks. Importantly, this author knew from the outset that not all of these strategies would work in combination. The process required identifying which methods were robust and which would fail

under real-world conditions. That is why the initial Maya textbooks, though valuable as prototypes, were simply functioning as transitional materials by the time they were printed. The most effective approaches identified through this process now form the foundation for future multilingual curriculum development across diverse linguistic and cultural communities.

Though ultimately superseded by more refined models, the 4th and 5th grade Maya STEM Plus textbooks played a critical transitional role. They marked the first time that the mangrove prototype methods were integrated into a full curriculum for minority-language primary schools, translating emergent design principles into structured classroom practice. Even as the author anticipated their eventual refinement, the books delivered vital lessons: not just on what worked, but on what could be let go. These quiet discoveries are embedded in every subsequent step of the project

The success of the 4th & 5th grade materials also demonstrated the methodological portability that would later be described in the *Hybridization* and *Ethnotranslation* frameworks. These textbooks drew on scientific content from outside the Yucatán Peninsula, yet were rendered locally meaningful through careful, collaborative adaptation (ethnotranslation). This confirms that when scientific perspectives from the Global South are paired with culturally grounded translation processes, the resulting materials can serve diverse communities without compromising scientific or cultural integrity. This portability is key to future scaling. Together, these experiences suggest that future multilingual science education initiatives must be designed not only for linguistic portability, but also for infrastructural adaptability across diverse writing systems and publishing environments. As biocultural education continues to expand across languages and landscapes, these early prototypes remind us that inclusion, iteration, and community authorship are not luxuries, they are the foundations of educational transformation.

In effect, the Maya textbooks became a test of whether scientific knowledge generated by researchers working in entirely different ecological, linguistic, and institutional contexts could be reorganized through ethnotranslation into a coherent Indigenous-language curriculum. Their success demonstrated that scientific knowledge need not originate within a community to become meaningful there, provided that adaptation is guided by culturally grounded processes and local educational expertise. Importantly, the scientific content evaluated in the Maya pilot was originally developed for audiences outside Quintana Roo and outside of Maya-speaking communities, making the successful classroom outcomes reported by Poot Cahun (2025) an especially strong demonstration of educational interoperability.

A particularly noteworthy outcome emerged from the broader developmental pathway that began with the multilingual mangrove prototypes and culminated in the Maya-language STEM Plus pilot. As the project evolved, educators, university faculty, and other stakeholders whose primary language was Spanish or English increasingly engaged with materials originally developed for Indigenous and Creole communities. In several instances, these individuals suggested that the multilingual, biocultural STEM Plus materials were comparable or superior to educational resources available in their own classrooms. While the present study was not designed to systematically evaluate such perceptions, these observations challenge conventional assumptions regarding the direction of educational innovation. Rather

than knowledge flowing exclusively from dominant-language institutions toward Indigenous and minority-language communities, the project suggests that community-authored, multilingual educational materials may generate innovations and pedagogical approaches that are recognized as valuable well beyond the communities for which they were originally developed.

These findings point not only to the transformative potential of polylingual science education, but also to a pathway for reshaping science curricula through linguistic and cultural sovereignty. As the STEM Plus model expands across additional bioregions, the lessons learned from these multilingual prototypes suggest that the future of conservation education lies not in translating science for communities, but in creating conditions through which communities become active participants in the creation, adaptation, validation, and transmission of scientific knowledge. In doing so, the model offers a scalable framework through which Indigenous and local communities can strengthen both biocultural resilience and scientific capacity while contributing to the global exchange of ecological knowledge.

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