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Ethnotranslation and Biocultural Education: Bridging Indigenous Ecological Knowledge and STEM Curricula

Etnotraducción y educación biocultural: Conectando el conocimiento ecológico indígena con los currículos STEM

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Abstract

The integration of Indigenous and Creole ecological knowledge into formal STEM[1] education is essential for environmental sustainability, cultural continuity and language revitalization. This paper introduces the Ethnotranslation Model, a participatory methodology that embeds local ecological knowledge systems within science curricula by anchoring instruction in biocultural constants, shared species, landscapes, and practices that align Indigenous, Creole and Western ecological knowledge. Through collaboration with Indigenous and Creole communities, ethnotranslation becomes not only a conservation strategy but also a movement for biocultural renewal. The model dismantles linguistic and cultural barriers, affirming that all languages, regardless of speaker population, are valid vehicles for scientific discourse and for the generation of ecological knowledge. Unlike conventional approaches, the framework is regionally scalable: materials can be culturally adapted across multiple linguistic communities within a shared bioregion with little to no ecological restructuring. Ethnotranslation thus offers a replicable model for science education that strengthens literacy, cultural identity, and conservation outcomes while honoring place-based ecological knowledge.

Keywords: Ethnotranslation, Biocultural Education, Indigenous Ecological Knowledge, STEM Integration, Cultural Preservation, Mesoamerica, Caribbean

Resumen

La integración del conocimiento ecológico indígena y criollo en la educación formal en STEM (Ciencia, Tecnología, Ingeniería y Matemáticas) es esencial para la sostenibilidad ambiental, la continuidad cultural y la revitalización lingüística. Este artículo presenta la etnotraducción, una metodología participativa que integra el conocimiento de los sistemas ecológicos locales en los programas de ciencias al anclar la instrucción en constantes bioculturales, especies compartidas, paisajes y prácticas que alinean el conocimiento ecológico indígena, criollo y occidental. A través de la colaboración con comunidades indígenas y criollas, la etnotraducción se convierte no solo en una estrategia de conservación, sino también en un movimiento para la renovación biocultural. El modelo desmantela las barreras lingüísticas y culturales, afirmando que todos los idiomas, sin importar el número de hablantes, son vehículos válidos para el discurso científico y para la generación de conocimiento ecológico. A diferencia de los enfoques convencionales, este marco es escalable regionalmente: los materiales pueden adaptarse culturalmente a múltiples comunidades lingüísticas dentro de una misma bioregión con poca o ninguna reestructuración ecológica.

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[1] Science, Technology, Engineering, Mathematics.

Así, la etnotraducción ofrece un modelo replicable de educación científica que fortalece la alfabetización, la identidad cultural y los resultados de conservación, al mismo tiempo que honra el conocimiento ecológico basado en el territorio.

Palabras clave: Etnotraducción, Educación biocultural, Conocimiento ecológico indígena, Integración de STEM, Preservación cultural, Mesoamérica, Caribe.

Introduction

Across the Caribbean and Latin America, Indigenous and Creole languages remain largely absent from science education. While international initiatives have promoted minority-language inclusion for decades, most notably UNESCO's 1953 *The Use of Vernacular Languages in Education*, these efforts rarely extend into STEM classrooms. Instead, such languages are often relegated to heritage or cultural programs, disconnected from scientific content. This approach preserves the past but leaves Indigenous and Creole peoples without a clear path into the future.

This exclusion undermines linguistic diversity and weakens student engagement with science. Even in majority-language classrooms, STEM education often struggles to sustain interest, resulting in poor retention and limited real-world application (OECD, 2016; Bybee, 2013). For Indigenous and Creole communities, linguistic exclusion further restricts access to scientific knowledge.

The absence of Indigenous and Creole languages in science education is striking when compared with the short evolution of Western scientific language. In Europe, early technical vocabulary emerged in ancient Greek, particularly through the writings of Aristotle (384–322 BCE), and was later systematized and transmitted through Latin, which for nearly two millennia remained the dominant medium of scholarship under Church authority (Lloyd, 1987; Harrison, 2007; Lindberg, 1992; Grafton, 1992). The seventeenth-century *Scientific Revolution* led by Francis Bacon, Galileo Galilei, and Robert Boyle gradually incorporated vernacular languages such as English, Dutch, French, Spanish, and Portuguese into scientific discourse (Dear, 2006; Goodman, 1990).

The *Enlightenment* period advanced this shift, with Carl Linnaeus's binomial nomenclature creating a Latin framework for species naming that endures today (Koerner, 1999).

Yet this so-called *Age of Reason* coincided with the Church's Inquisition, revealing a Europe that expanded scientific inquiry even as it violently policed knowledge and thought through public spectacles of punishment such as the *auto de fé* (Kamen, 1998; Grafton, 1992; Lindberg, 1992).

Meanwhile, the First Nations of *Abiayala*[2] (the American continents) demonstrated that Europe did not monopolize science. The Maya, for example, were astronomers, engineers, and mathematicians who independently developed the concept of zero, created precise solar calendars that still function today, and sustained large cities through advanced ecological knowledge and agroforestry (Aveni, 2001; Sharer & Traxler, 2006). Across *Abiayala*, Indigenous peoples possessed detailed vocabularies for describing environments and technologies (Cajete, 2000; Medin & Bang, 2014). Fishing, hunting, and agriculture evolved through trial and error (Battiste & Henderson, 2000; Deloria, 1997), what Western science would later call experimentation. Scientific knowledge was transmitted and refined across generations (Kimmerer, 2013; Cajete, 1994), amounting to what can only be described as a thousand generations of peer review. Ethnobiological scholarship has long documented the internal structure and classificatory rigor of Indigenous ecological knowledge systems (Puri, 2015).

Research from ethnobiology highlights the dynamic nature of Indigenous and local ecological knowledge systems, including their intergenerational transmission and interaction with scientific knowledge practices (Stepp, 2016). Ethnobiological research further demonstrates that Indigenous ecological knowledge systems are internally structured, taxonomically precise, and grounded in systematic observation and practice rather than informal or ad hoc tradition.

When Europeans arrived, Indigenous languages already had encoded sophisticated ecological and technological understanding. However, these achievements were violently suppressed.

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[2] *Abiayala*, meaning "Land of Life" or "Mature Land" in the Guna language, is the term the Guna people use for the American continents. The designation was popularized by Aymara leader Takir Mamani, founder of the Tupaj Katari Indigenous rights movement. As the project expands across the Caribbean, Mesoamerican, and Isthmian corridors, the name *Abiayala* honors the interconnected landscapes and living cultures of the Americas, reflecting both scientific continuity and a broader cultural awakening that affirms a decolonial approach to science education.

For example, in 1562 Friar Diego de Landa of the archdioceses of the Yucatán presided over the *auto de fe* at Maní, where Maya codices, repositories of astronomical, mathematical, and ecological knowledge were burned as heretical (Restall, 1997; Clendinnen, 1987). Such destruction epitomized the broader denial of Indigenous science and the decline of local languages (Mignolo, 2003).

These contrasts reveal a foundational problem in post-contact education systems. A deep historical asymmetry between Indigenous and European languages underpins the need for *ethnotranslation*. Maya hieroglyphic writing is securely attested by 200–300 BCE (Saturno, Stuart, & Beltrán, 2006), and evidence of sophisticated Maya scientific terminology, especially in astronomy, engineering, and agriculture appears by the start of the Common Era (Aveni, 2001; Lucero, 2006). In contrast, the European vernaculars that later shaped colonial education systems entered writing much later: Old English by the 7th century CE (Hogg & Denison, 2006), Old Dutch by the 8th–9th centuries CE (Donaldson, 1983), Old French in 842 CE (Kibler, 1984), Old Spanish by ca. 950–1000 CE (Penny, 2002), and Portuguese by the late 12th century (Teyssier, 1994). Scientific registers in Europe emerge even later, only becoming standardized during the sixteenth to eighteenth centuries, culminating with Linnaean taxonomy (Lindroth, 1973).

This asymmetry was compounded by deliberate acts of epistemicide (Santos, 2014; 2018). After first contact in 1502 CE, further losses followed, including the 1562 *auto de fe* of Maní, which destroyed nearly all of the Maya written record (Restall, 1997; Sharer & Traxler, 2006). Thus, modern claims that Indigenous languages "lack scientific terms" overlook two realities: (a) Maya languages developed written scientific lexicons more than a millennium earlier than European vernaculars, and (b) much of this corpus was violently destroyed by the Church. See figure 1. *Ethnotranslation* directly addresses these historical distortions by rebuilding *Sak bejo'ob* [3] for Indigenous scientific equivalence.

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[3] *Sak bejo* is a term for a raised, paved road built by the ancient Maya. These roads were used for practical purposes like connecting cities and ceremonial centers, as well as for social, political, and religious functions. *Sak bejo'ob* is the plural form which most closely aligns with the English term pathways.

This work is therefore both an academic intervention and an act of restitution, restoring scientific authority and linguistic legitimacy to Indigenous and Creole peoples.

The history of zero illustrates a striking asymmetry in the global circulation of scientific knowledge. Zero emerged independently in multiple knowledge systems, including Mesopotamia (as a positional placeholder), South Asia (as a formally defined number), and the Maya civilization world, where it functioned fully within calendrical, astronomical, and mathematical systems centuries before European contact (Ifrah, 2000; Kaplan, 2000; Stuart, 2011). While European languages gradually adopted both the concept and the term for zero through Arabic mediation between the eighth and sixteenth centuries (Menninger, 1969; Joseph, 2011), Maya mathematical knowledge followed a fundamentally different trajectory. By the time Europeans first encountered Maya traders in the early sixteenth century, zero had long been operational within Maya science (Coe & Van Stone, 2005); yet rather than entering global scientific exchange, this knowledge system was actively suppressed. The 1562 *Auto de Fe* of Maní, during which ecclesiastical authorities under Diego de Landa destroyed large portions of the Maya written corpus as heretical, represents not a failure of transmission but a deliberate epistemic rupture (Landa, 1566/1937; Clendinnen, 1987). The juxtaposition of European linguistic adoption of zero with the contemporaneous destruction of Maya scientific texts underscores how the development of modern scientific canons was shaped not only by diffusion and innovation, but also by selective preservation and institutionalized erasure of Indigenous knowledge systems. See Figure 2.

The Maya is only one example; diverse Indigenous civilizations across *Abiayala* developed complex scientific and technological lexicons, whether expressed in written scripts (e.g., Zapotec, Mixtec, Nahuatl) or in rigorously structured oral and record-keeping systems (e.g., Andean, Amazonian, and North American traditions) (Boone & Mignolo, 1994; Urton, 2003).

Similar dynamics shaped the ecological knowledge of Afro-descendant communities across the greater Caribbean basin. Enslaved Africans and Afro-Caribbeans developed highly sophisticated systems of agroforestry, forest navigation, and coastal resource management (Carney, 2001; Price & Price, 1999; Palacio, 2001).

Research on West African tidal irrigation, African-derived rice cultivation systems, and forest science demonstrates that Afro-descendant ecological knowledge functions as a full scientific tradition grounded in long-term observation, experimentation, and environmental adaptation (Fields-Black, 2008; Carney & Rosomoff, 2009). Like Indigenous communities, Afro-descendant peoples carried ecological and linguistic systems that were systematically devalued under colonial rule, resulting in a parallel form of epistemicide that obscured the scientific sophistication embedded in Creole and Indigenous languages.

This restitutionary effort resonates with the work of López-Maldonado, (2017; López-Maldonado et al., 2024), and with Indigenous governance scholars who emphasize that Indigenous knowledge systems must be translated and mobilized under conditions of Indigenous authority and rights-based participation (Cariño & Colchester, 2010). Together, these perspectives affirm that Indigenous observation and interpretation of ecological change constitute living scientific frameworks, aligning closely with the epistemic and pedagogical aims of ethnotranslation.

The development of this model has been shaped by years of collaboration and by the researcher's own process of unlearning and relearning what counts as science. That process began long before formal academic training. In 1997, during his first experience abroad, he lived among the Maasai and Pokot peoples of East Africa, assisting with footbridge construction and water projects. Living with families and listening to elders discuss hunting and land use shaped his earliest understanding of diverse ecological knowledge systems. Although he lacked the academic vocabulary at the time to describe what he was witnessing, the foundations of this work were being laid in the Maasai Mara and the deserts of West Pokot.

Its origins, however, go back even further. Like many of the Indigenous and Creole communities with whom the researcher now collaborates, his first lessons in ecology came not from textbooks but from relatives. In the Lowcountry of South Carolina, his Aunt Ima Lee taught him to catch his first fish, a bream (*Lepomis macrochirus*) at the age of three, an early and formative lesson in ecological understanding. His father, Bobby Thigpen, continued that informal education.

Although he would never have used the term ecology, he would simply say, "I know how to put fish in the boat." The researcher's family line carried deep reservoirs of rural ecological knowledge, but that transmission ended abruptly with several of his cousins, leaving him and one other cousin as the last to carry that inheritance forward.

Before entering university, the researcher's ecological understanding had been shaped entirely through lived experience and learning from elders. Long before his first biology class, his feet had been planted firmly in the tidal rhythms, forests, and estuaries of the South Carolina Lowcountry and, later, in other ecosystems around the world. His first formal exposure to biology, an undergraduate course titled Coral Reef Ecology, did not replace these earlier ways of knowing; it illuminated them. With each additional biology course, he began to see the connections between the traditional ecological knowledge he had inherited and the principles of Western science. In time, he realized that he was standing at the nexus where multiple ways of knowing converged where experiential knowledge, Indigenous and Creole ecological perspectives, and Western scientific frameworks met. This vantage point did not diminish his original ecological grounding; it expanded it, revealing a broader landscape of understanding that carried the same charge as a child realizing that what seemed known and bounded was, in fact, expansive and still unfolding.

Although the researcher is an academic working in Indigenous and Creole regions, the content and epistemic grounding of this work derive from community knowledge keepers; his contribution lies in coordinating the academic structure needed to support and protect that knowledge, not defining it.

This way of knowing shaped the researcher's academic trajectory. During his university studies, he began to connect the theoretical frameworks introduced in the classroom with the observational knowledge he had acquired through lived experience and fieldwork abroad. A Benjamin A. Gilman International Scholarship supported his internship with the Northern Fishermen's Cooperative Society Ltd. in Belize City, where he conducted stable isotope analyses of the Caribbean spiny lobster (*Panulirus argus*) food web (Creed & Thigpen, 2007) and worked directly alongside Garifuna, Kriol and Maya fishers.

From the outset, he recognized and respected the depth of their ecological knowledge, seeking to learn from it so that, he could learn how to *put fish in the boat* in the Caribbean.

That respect soon became mutual. Fishers recognized that the researcher listened to learn rather than to correct, and they began to approach him for assistance. They were aware that the fishery no longer functioned as it had when they were young and hoped he might offer insights. In turn, they invited him to sea and taught him what their grandfathers had taught them. He came to realize that their ecological knowledge was not merely parallel to what he had learned in South Carolina, it was, in many instances, identical. These patterns echoed the insights he had first encountered years earlier in East Africa, where Maasai and Pokot elders described similar relationships between people, animals, and landscape. Comparable resonances later appeared within the Maya Forest Corridor, revealing the robustness and universality of ecological knowledge systems across ecoregions and cultures. This recognition became the foundation for the *Ethnotranslation Model* described here and the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen, 2025).

Conversations with fishers along the Mesoamerican Barrier Reef System came naturally to the researcher. They observed the rapid changes unfolding in their waters, and he could readily understand their perspectives. The greater challenge arose in communicating this urgency to his academic advisors at *Appalachian State University*. Many lacked frameworks to engage meaningfully with local ecological knowledge, while he lacked the scholarly vocabulary to articulate what he was witnessing because it did not yet exist. At times, the experience felt akin to describing powered flight across the English Channel to the Montgolfier brothers before they had ever filled their first balloon. He was attempting to explain something that belonged to a future his mentors could not yet conceptualize, using intellectual tools and terminology that had not yet been developed.

This gap compelled the researcher to articulate a set of interrelated conceptual frameworks and theoretical constructs that now form the foundation of this series of papers.

Because the work did not fit neatly within established disciplinary categories, it was often misunderstood or constrained by inappropriate theoretical boundaries. The present article, together with the *Hybridization Hypothesis of Ecological Knowledge Systems*, represents the most formal effort to define, systematize, and situate these emerging theories and frameworks. The project as it exists today was shaped by early experiential and relational learning, fishing in the Lowcountry of South Carolina, tracking game with the Maasai and Pokot, and learning from Indigenous and Creole fishers in Belize. Together, these experiences constitute the epistemological and pedagogical foundation of the *Ethnotranslation Model*.

The *Ethnotranslation Model* aligns with international frameworks that call for recognizing Indigenous, Creole and minority languages in science and education. The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP, 2007), the Decade of Ocean Science for Sustainable Development (2021–2030), and the International Decade of Indigenous Languages (2022–2032) all emphasize integrating Indigenous languages and knowledge into sustainability efforts. Similarly, the IUCN's Target 22 identifies Indigenous and local ecological knowledge as central to biodiversity protection, while the Cartagena Convention underscores the need for regional cooperation across the wider Caribbean[4].

Together, these frameworks affirm the relevance of the *Ethnotranslation Model* as a bridge between Indigenous, Creole, and Western science in education. By centering biocultural constants and embedding ecological knowledge in multiple languages, the model shows how culturally grounded curricula can enhance science education, revitalize endangered languages, and strengthen conservation outcomes.

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[4] Two related terms with distinct emphases are used in this paper. *Wider Caribbean* refers to all Caribbean Island nations as well as ocean front jurisdictions of Latin America that front the Caribbean Sea. *Greater Caribbean Basin* is used in the same broad geographic sense but include linguistic and cultural communities living within the inland river basins of Latin America whose waters ultimately flow into the Caribbean Sea.

Methods

The *Hybridization Hypothesis* framework underpins the *Ethnotranslation Model*. It asserts that the integration of Western science and traditional ecological knowledge (TEK) should not be treated as separate or competing systems, but rather as complementary traditions capable of co-producing ecological knowledge and educational content that is both culturally grounded and scientifically rigorous (Thigpen, 2025). The framework presented here guides the application of this model across diverse linguistic and ecological contexts, enabling materials to remain interoperable among multiple linguistic groups within shared ecoregions while allowing for culturally specific articulation in each language community.

Relational Learning

Before detailing specific data sources and collection procedures, it is necessary to clarify the epistemic and ethical orientation that guided how knowledge was generated, interpreted, and translated throughout this research.

The methodological approach employed in this research is best described as *relational learning,* a process through which knowledge is acquired through sustained, reciprocal relationships rather than through extractive data collection or formal interviewing alone. Relational learning centers listening, shared time, trust-building, and iterative dialogue, positioning the researcher primarily as a learner accountable to community-defined relational norms and ethical obligations. This approach was employed consistently across the long-term research program that informed both the present study and the earlier formulation of the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen, 2025).

Although developed independently, this relational learning approach converges closely with the Maya epistemic practice of *Tsikbal* (Castillo Cocom *et al.,* 2015). *Tsikbal* is a culturally governed form of dialogic exchange through which knowledge is shared, refined, and transmitted relationally over time, emphasizing reciprocity, respect, and collective sense-making.

The convergence between *relational learning* and *Tsikbal* lies not in methodological derivation, but in a shared relational logic: knowledge emerges through dialogue, lived experience, and responsibility to community rather than through individual extraction or ownership.

This convergence was independently recognized during the review of Hilario Poot Cahun's master's thesis, *Educación ambiental intercultural: desarrollo y pilotaje de libros en lengua maya para niños de primaria indígena en Quintana Roo* (Poot Cahun, 2025), which was deeply grounded in the same long-term relational learning methods that informed the *Hybridization Hypothesis.* During the thesis review process, his advisor, Angel Abraham Ucan Dzul, M.Ed., an Indigenous scholar familiar with Maya epistemological traditions, identified strong parallels between the methods described in the thesis and *Tsikbal* as articulated in the literature and suggested that the *Tsikbal* framework be cited. Following discussion, Poot Cahun and this researcher agreed. This unsolicited recognition by Indigenous scholars provided important external affirmation that the relational learning methods employed over time were epistemically aligned with Indigenous dialogic traditions, despite having been developed independently.

This convergence proved critical to the success of the ethnotranslation process. Because ecological knowledge was received through relational learning rather than elicited through formalized data-gathering, scientific concepts could be re-articulated through dialogue and shared ecological reference points, enabling translation practices that respected epistemic sovereignty and linguistic integrity.

Data Sources and Collection Methods

Empirical evidence for this study is drawn from five interrelated sources:

- **Curriculum Piloting.** STEM Plus[5] materials were developed and tested in multiple classrooms, including a two-year pilot study in six Indigenous Maya primary schools in

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[5] STEM Plus refers to an expanded model of Science, Technology, Engineering, and Mathematics education that integrates language, culture, and local ecological knowledge into STEM instruction. The model emphasizes biocultural and multilingual learning, allowing students to engage scientific concepts through their own linguistic and cultural frameworks while strengthening literacy, identity, and environmental stewardship.

Quintana Roo, México (Poot Cahun, 2025), and smaller-scale trials in Kriol and Mopán-speaking classrooms in Belize (Thigpen, 2025). These pilot sites served simultaneously as implementation contexts and observation settings for real-time refinement.

- **Collaborative Design and Cultural Validation.** Materials were co-developed and reviewed with Indigenous and Creole knowledge keepers, who contributed insights, adapted scientific terms into local frameworks, and guided linguistic decisions such as transliteration or the creation of neologisms. These processes were documented through field notes and iterative feedback cycles. Comparable participatory methodologies appear in López-Maldonado's (2017) cenote-conservation research in Yucatán, where local categories of water and place guided both data collection and scientific interpretation, exemplifying co-production between Indigenous and Western frameworks.
- **Comparative Literature Review and Scientific Collaboration.** Before finalizing and printing, draft materials were systematically compared with existing academic and scientific literature to ensure accuracy and alignment with current ecological research. In addition, Thigpen developed the original content in collaboration with biologists primarily from the Global South, who had experience working with and respecting Indigenous and Creole peoples. This dual process of scholarly review and scientific partnership provided an added layer of rigor and cultural accountability. None of the original content was created for either Quintana Roo nor a Maya audience.
- **Community Testimonials and Observational Feedback.** Formal and informal interviews, parent and teacher testimonies, and classroom reflections captured changes in student engagement, identity affirmation, and environmental awareness. These qualitative accounts such as a mother's observation that her son began insisting on speaking only Maya at home functioned as embedded data guiding model development (Thigpen 2025).
- **Embedded Quantitative Data.** Although primarily qualitative, the study incorporates quantitative findings from the formal evaluation conducted by Hilario Poot Cahun (2025) as part of his master's thesis research. This two-year case study employed a mixed-methods design to assess student outcomes in six Maya primary schools. Key quantitative indicators included:

- Increased frequency of Maya language use at home (based on surveys and parent reports).
- Improved student environmental knowledge (pre- and post-assessments).
- Documented gains in classroom engagement and teacher-reported participation.
- Adoption of bilingual instructional strategies by educators in response to improved student fluency.

These case study data were analyzed descriptively and triangulated with qualitative testimonies, providing classroom-grounded validation of the model.

This blended methodology reflects the principles of epistemological pluralism by prioritizing community perspectives, linguistic equity, and ecological relevance, consistent with rights-based approaches to Indigenous knowledge governance that caution against extractive translation practices (Cariño, 2012). It replaces extractive data collection with collaborative approaches rooted in knowledge co-production, linguistic continuity, and curriculum development aligned with UNDRIP, the UNESCO Decade of Indigenous Languages, and the IUCN's Target 22 on Indigenous ecological knowledge. By bridging biological, linguistic, and educational approaches, the *Ethnotranslation Model* combines participatory curriculum design with both narrative evidence and measurable indicators of classroom transformation. In doing so, the model demonstrates theoretical robustness for the sciences, rights-based relevance for policy, and practical validity for educational practice positioning it for regional scalability.

Central Hypothesis

The integration of Indigenous, Creole, and Western ecological knowledge through *biocultural constants* and collaborative *ethnotranslation* produces multilingual STEM Plus materials that are academically robust, culturally relevant, and regionally scalable.

Research Questions

- How can science education be made culturally and linguistically relevant for Indigenous and Creole communities while maintaining scientific accuracy?

- What role do biocultural constants; shared species, ecosystems, and ecological relationships play in aligning Western science with traditional ecological knowledge systems?
- How can transliteration and other adaptation strategies support the effective use of Indigenous and Creole languages in STEM education?
- In what ways do collaboration with local knowledge keepers enhance the accuracy and cultural resonance of these curricula?
- Can *ethnotranslated* materials be adapted across multiple linguistic communities within shared ecoregions without ecological restructuring?
- What impacts do these materials have on students' language use, cultural identity, environmental awareness, and classroom engagement?
- How can the *ethnotranslation* model support international frameworks such as UNDRIP, SDG's, the UNESCO Decade of Indigenous Languages, the IUCN Target 20, and the Cartagena Convention?
- What institutional or political challenges arise in implementing a multilingual, community-guided, rights-based framework, and how can they be addressed?

Hybridization Hypothesis

Central to ethnotranslation is the Hybridization Hypothesis of Ecological Knowledge Systems, which views Western science and traditional ecological knowledge (TEK) as complementary, mutually enriching systems rather than competing ones (Thigpen, 2025). Building on Aikenhead and Ogawa's (2007) concept of cultural border crossing, the Hybridization Hypothesis emphasizes biocultural constants as the foundation for co-produced, locally grounded content. This relationship between language, culture, and biodiversity parallels the findings of Loh and Harmon

(2005), who demonstrated that linguistic diversity closely mirrors species richness across ecoregions, a pattern that underpins the concept of biocultural constants.

The ethnotranslation framework also underscores the importance of pedagogy: teaching must not merely prepare students to cross epistemological borders as described by Aikenhead and Ogawa (2007) but must instead build a bridge between ecological knowledge systems and then teach on that bridge. This bridge allows teachers and students to operate from both epistemic realms at once, rather than leaving one behind to enter the other. Crucially, the ethnotranslation model does not attempt to crowd every linguistic group in an ecoregion onto a single bridge. Instead, it uses biocultural constants to build a system of bridges for these linguistic and cultural communities, ensuring that learning remains rooted in local epistemologies rather than forcing diverse peoples into a homogenized pedagogical space.

In practice, this means creating learning environments where students move confidently between worldviews, strengthening both cultural identity and scientific literacy without subordinating Indigenous or Creole systems of thought.

Afro-descendant ecological knowledge further demonstrates the need for hybridized pedagogies. Studies of Afro-descendant agroforestry, African-derived ecological systems, Garifuna fisheries, and Kriol coastal navigation show that African diaspora communities developed ecological sciences that parallel Indigenous knowledge systems and often converge with Western biology at the level of applied practice (Moberg, 1997; Carney & Rosomoff, 2009; Bilby, 2005).

Incorporating these knowledge systems through ethnotranslation is essential for regions like the Caribbean, where Indigenous, Creole, and Afro-descendant ecological traditions coexist and collectively inform conservation and climate resilience.

This approach is grounded in the principle of epistemological pluralism, recognizing multiple valid ways of knowing as essential for fostering scientific literacy, cultural continuity, and ecological stewardship. Emerging through participatory curriculum development with Indigenous and coastal communities in Latin America and the Caribbean, the *Hybridization Hypothesis* (Thigpen 2025) has since informed the design of STEM Plus educational materials. These blend Western biological frameworks with Indigenous languages and place-based ecological knowledge delivered in local contexts. The model also provides a practical framework for education ministries and language policy agencies seeking to integrate Indigenous and Creole language and knowledge into national curricula. Its effectiveness was validated in Maya-speaking primary schools in Quintana Roo, México, through Hilario Poot Cahun's (2025) master's thesis, which documented classroom outcomes.

López-Maldonado and Berkes (2017) document similar epistemological integration within Maya groundwater governance, showing that Indigenous cenote management operates simultaneously as cultural practice and applied ecological science. Their findings illustrate that hybridized ecological reasoning is already embedded in regional governance systems, providing an empirical parallel to the framework advanced here.

Furthermore, the *Hybridization Hypothesis* challenges deficit narratives about non-dominant languages by embedding Indigenous and Creole languages at the core of science instruction and elevating them as tools for both scientific inquiry and conservation (Thigpen, 2025). This perspective is consistent with the goals of the *United Nations Declaration on the Rights of Indigenous Peoples* (UNDRIP, 2007), the *Charter on Language Policy and Language Rights in the Creole-Speaking Caribbean* (ICCLR, 2011), the *UN Decade of Ocean Science for Sustainable Development* (2021–2030), and the *UN Decade of Indigenous Languages* (2022–2032).

The development of STEM Plus educational materials follows a two-phase, multi-step *ethnotranslation* methodology designed to ensure both scientific accuracy and cultural relevance:

Phase I – Biocultural Content and Curricula

1. Development of Biocultural Content

- In the initial stage, collaboration focuses on biologists and ecologists who specialize in the targeted ecoregion's species and ecosystems and who respect local ecological knowledge systems.

- The principal investigator (PI) and these local biologists will already have a working knowledge of the flora and fauna that inhabit the area, and in some cases even an understanding of which species are most meaningful to the local community. Using species range maps and the IUCN Red List (International Union for Conservation of Nature [IUCN], 2024), they determine initial priority species for educational content.

- Only one or two themes should be developed prior to working directly with local knowledge keepers. These themes should center on charismatic or keystone species that provide strong ecological anchors and resonate across communities.

- As content is created, careful attention is given to the identification and incorporation of *biocultural constants*, shared species, ecosystems, and cultural practices that align Western and local ecological knowledge.

- It is valuable, though not required, to involve local knowledge keepers during this phase. Collaboration may not always be practical at this stage for logistical or institutional reasons, but, when possible, their participation strengthens cultural relevance and ecological accuracy. However, the involvement of local knowledge keepers is paramount in Phase II.

2. Biocultural Curricula

- The selected themes are then reorganized into age-appropriate curricula, tailored to specific grade levels and aligned with the ecological context of the ecoregion, biome, or species range.

- Translation documents (trad docs) are prepared to share with the community.

Phase I is preparatory in nature, laying the scientific and curricular foundation for later collaboration with knowledge keepers, communities, and educators in Phase II, when full cultural and linguistic integration takes place. It also provides the PI with a practical example of locally resonant ecological content to begin direct collaboration with knowledge keepers and local *ethnotranslators* to initiate the rearticulation of materials for community use.

Through this process, the materials are made ready for knowledge keepers and linguists to begin the second phase of *ethnotranslation*, reframing ecological concepts through the linguistic, metaphorical, epistemic, pedagogical, and cultural structures familiar to local communities, ensuring that the outcome is not merely a translation but a cultural and epistemic re-articulation of conservation education without changing the underlying ecological concepts. This sets the stage for direct and ongoing consultation with the local community as new content is developed in Phase II.

This iterative, community-led process reflects global best practice in biocultural education. Maffi and Woodley's *Global Sourcebook on Biocultural Diversity Conservation* (2010) shows that when local communities lead the integration of their languages, values, and ecological knowledge into pedagogical materials, outcomes are stronger. Their worldwide survey found that curricula co-developed with Indigenous communities and rooted in linguistic and ecological realities foster both biodiversity protection and cultural resilience. This conclusion parallels the ethnotranslation process, which begins with community engagement and culminates in culturally grounded, scientifically rigorous content.

Special attention is also given to respecting Indigenous rights to language, cultural expression, and participatory decision-making, as outlined in frameworks such as UNDRIP (United Nations, 2007).

In practice, the methodology supports the documentation and revitalization of minority languages by requiring the generation, standardization, and use of ecological terminology often absent from formal Indigenous education.

Unlike initiatives that focus on a single Indigenous or Creole linguistic group, the *Ethnotranslation Model* is designed for adaptation across multiple linguistic communities within shared ecological zones. By anchoring STEM content in biocultural constants, recurring species, landscapes, and ecological relationships, STEM Plus materials remain scientifically grounded and ecologically meaningful across bioregions. This interoperability allows content to be reused, recontextualized, and collaboratively refined for different linguistic groups with minimal ecological restructuring.

For instance, materials developed for Yucatec Maya speakers in Quintana Roo can be adapted for Mopán or Kriol speakers in Belize, or for Miskito communities in Honduras, with careful linguistic and cultural validation.

This scalable, pluralistic model sets *ethnotranslation* apart from more narrowly focused language inclusion projects. It enables a coordinated, multilingual approach to conservation education across regions such as the wider Caribbean and Latin America, where ecological continuity transcends national and linguistic boundaries.

Although the process centers on linguistic and cultural adaptation for Indigenous and Creole communities, it also strengthens environmental learning among dominant-language speakers. When STEM Plus materials are made available in Spanish, English, or other widely spoken languages, they introduce all learners regardless of heritage to locally grounded ecological content. Designed with an emphasis on sustainability, these materials foster both conservation awareness and community engagement.

The Role of Biocultural Constants and Local Ecological Knowledge Systems

Biocultural constants, shared ecological and cultural features that remain consistent across linguistic and cultural communities play a crucial role in bridging Western science with Indigenous and Creole ecological knowledge systems (Thigpen, 2025). Recognition of biocultural constants strengthens ecological understanding and supports conservation efforts.

One example is the parallel ecological knowledge developed by Indigenous and Creole communities regarding the Caribbean red snapper (*Lutjanus purpureus*), the West Indian manatee (*Trichechus manatus*), and the military macaw (*Ara militaris*). Because these species inhabit ecosystems spanning multiple countries, local communities have generated distinct yet overlapping knowledge that often converges (Toledo & Barrera-Bassols, 2008), underscoring the robustness of *biocultural constants* in ecological understanding (Thigpen, 2025).

This pattern echoes broader research showing that co-evolved relationships among language, ecological practice, and biodiversity are central to ecosystem resilience (Maffi, 2007), and supports Maffi's (2002) argument that conservation must address both biodiversity and the vitality of local languages.

The invasion of lionfish (*Pterois* spp.) further illustrates the importance of multilingual conservation. Its rapid spread across the Caribbean has disrupted fisheries in many linguistic and cultural communities. Despite limited direct communication, fishers' ecological observations and responses have often aligned, reinforcing the role of *biocultural constants* in shaping shared conservation practices.

The researcher's curiosity about community-based ecological knowledge began well before his entry into academia. In 1997, he lived among the Maasai and Pokot in Kenya, assisting with footbridge construction and drilling boreholes to provide clean drinking water. He lived alone within these communities, staying in traditional homes made of cow dung and mud, and was often the only non-African present. Community members later recalled his willingness to live as they lived, sharing their food, learning their languages, and listening with respect.

What left the deepest impression on the researcher was living with families and learning through participation. Whenever elders spoke about hunting, or development priorities, he listened closely, absorbing knowledge passed down through generations, knowledge that reached back to the time when the earliest hominids traversed the same paths he walked each day. At the time, he regarded these exchanges as the privilege of being welcomed into another way of knowing, without yet recognizing their pedagogical or academic significance.

Years later, while researching the Indigenous and Creole lobster fishery of the western Caribbean, he came to appreciate the value of those early lessons. They provided a reference point for understanding how ecological knowledge is situated, inherited, and applied within multilingual, resource-dependent communities. That experience continues to shape the participatory, language-conscious pedagogy he brings to both research and education today.

This shift in approach led to the development of the *Ethnotranslation Model* introduced here. The concept is inspired by *etnoeducación*, as expressed by the Wayuu[6] people of Colombia and Venezuela. *Etnoeducación* is an educational model that enables the Wayuu to engage with Western educational frameworks while maintaining cultural autonomy. It is at once a pedagogical strategy and a form of resistance, safeguarding cosmological beliefs and practices against external imposition and asserting the Wayuu people's right to define their own educational path (Botero, 2015; Sánchez Castellón, 2020).

Building on this premise, the *Ethnotranslation Model* was developed as a methodology for producing educational materials that honor native ecological knowledge systems while incorporating contemporary ecological science. Unlike conventional translation models, ethnotranslation first adapts scientific concepts to the cultural context and then translates them into local languages in ways that align with community worldviews, norms, and ecological understandings.

This positions local languages not merely as vehicles of translation but as epistemological infrastructures, pedagogical systems through which ecological knowledge is generated, organized, transmitted, and renewed across generations.

Ethnotranslation also complements the *Hybridization Hypothesis of Ecological Knowledge Systems*, which emphasizes epistemological integration across linguistic and cultural domains (Thigpen, 2025). This framework aligns with studies indicating that transliteration in scientific education can facilitate conceptual comprehension and reduce cognitive load among young learners, thereby promoting familiarity with scientific discourse while preserving the linguistic integrity and pedagogical capacity of each language (Grami, 2019). As Aminta Peláez Guariyu, a Wayuu collaborator, told the researcher, this work "*demonstrates that my language is equal to all other languages*." Her words encapsulate the central aim of biocultural education: to affirm the

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[6] The Wayuu are a matrilineal society native to the Guajira Peninsula of northern Colombia and northwestern Venezuela. They have long resisted Western ideological influence and consider Marine Conservation without Borders as their ally (Thigpen etal 2017).

equal epistemic value of all languages and knowledge systems in shaping ecological understanding and stewardship.

Phase II – Translation, Adaptation, and Pedagogical Integration

Building on the preparatory work of Phase I, Phase II shifts to community-guided processes where ecological content is rearticulated through collaboration with local knowledge keepers, linguists, and educators.

1. Translation and Cultural Adaptation

- **Trad Docs** prepared in Phase I are shared with knowledge keepers, who review the content and identify any ecological details the biologists may have missed. Their experience-based opinions are respected, and suggested additions are recorded in both the local language and the majority language column of the trad doc so the biologists can learn from these amendments in order to generate more robust content in the future.

- Scientific concepts are then reframed through linguistic, metaphorical, epistemological, pedagogical, and cultural structures familiar to local communities, ensuring accuracy while embedding knowledge in culturally meaningful forms with minimal or no ecological restructuring.

- Each chapter includes images of the focal species, drawn from across its geographic range to demonstrate that the ecological theme is not just a local issue but part of a broader conservation challenge. At the same time, local images are prioritized, including photos of community members engaging in activities directly connected to the chapter's theme so the material remains grounded in local realities.

- Each chapter also incorporates discussion of climate change and its effects on the focal species or ecosystem, helping students understand how global environmental shifts are expressed in local contexts.

2. Community Review and Refinement

- Draft materials are piloted in classrooms and community workshops with students, teachers, elders, and parents.
- Feedback is incorporated through iterative revisions to improve clarity, engagement, and cultural authenticity.

3. Educational Implementation and Pedagogical Training

- Finalized materials are integrated into formal curricula at the appropriate grade levels.
- Educators receive training in culturally relevant and linguistically inclusive pedagogy, equipping them to use both Western scientific frameworks and Indigenous / Creole ecological knowledge as coequal sources of insight[7].
- Phase II represents the full enactment of ethnotranslation: ecological concepts are re-articulated in forms that are scientifically rigorous, culturally resonant, and pedagogically effective, without altering the underlying ecological concepts. The process produces hybridized texts where Western and local ecological knowledge systems remain visible yet interdependent, creating conservation education that is both inclusive and ecologically grounded. From this point forward, the PI continues to consult directly with the local community as new content is developed, ensuring that subsequent materials remain rooted in both scientific integrity and cultural legitimacy.

The *Ethnotranslation Model* emphasizes participatory collaboration with Indigenous and Creole knowledge keepers, reflecting the rights to cultural autonomy, education in Indigenous and Creole languages, and protection of traditional knowledge systems outlined in UNDRIP (United Nations,

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[7] Marine Conservation without Borders is leading an effort with *la Universidad Intercultural Maya de Quintana Roo* to develop university-level classes that prepare Maya student teachers to use these materials, as well as modules for teacher recertification programs. The goal is not only to prepare the Maya student teachers of tomorrow but also to design classes that can be exported to other universities and linguistic communities, and perhaps even to develop graduate programs that train Maya and other linguistic communities to develop their own materials.

2007). Rather than imposing Western ideologies, *ethnotranslation* seeks to avoid the risk long present in science education of functioning as a subtle form of colonialism when the breadth and depth of Western science are prioritized at the expense of local systems of ecological knowledge.

This approach follows Franz Boas' theory of *Cultural Relativism* (1887), which holds that each culture should be understood in its own context. By grounding concepts in ecological, cultural, and linguistic frameworks before translation, *ethnotranslation* ensures that scientific knowledge is introduced in ways that respect cultural integrity.

Transliteration is central to ethnotranslation, making scientific terms both recognizable and accessible to Indigenous and Creole speakers. It preserves scientific accuracy while honoring linguistic and cultural diversity. Direct translation is often infeasible because many Indigenous languages lack equivalents, and neologisms can be cumbersome for young learners (see Table 1). By contrast, transliteration adapts terms to local phonetic structures while maintaining their original scientific meaning.

For example, in STEM Plus materials the term *ecosystem* has been rendered as *pachkuxtal* in Mopán (Thigpen et al., 2021), *sukua'ipa mmapakat* in Wayuu (Thigpen et al., 2018), and *dî sangkaka karak balna ûkana* in Ulwa (Thigpen et al., 2020). These translations are accurate but unwieldy and diverge from the terminology used in university-level biology (Grami, 2019). Transliteration, by contrast, provides standardized scientific terms in forms compatible with local orthographies, enabling students to access global ecological concepts while maintaining cultural relevance (see Table 2).

Although not a longstanding convention in Indigenous linguistic traditions, transliteration has long shaped Western scientific vocabulary. Terms like *ecosystem* or *carbon dioxide* derive from Latin and have been localized across European vernaculars according to their orthographies. Not all concepts are best transliterated, however. The term *riparian zone*, for instance, is often translated, producing *zona ribereña* in Spanish or *Uferzone* in German. Many Indigenous languages also contain precise equivalents rooted in local ecological knowledge; in Maya Yucateco, *U jáal ja'* describes riparian areas, showing how traditional ecological knowledge can at times provide more appropriate terms than transliteration, offering students culturally grounded vocabulary that deepens both linguistic and ecological learning.

In practice, a teacher might introduce both the traditional Maya Yucateco term *U jáal ja'* for riparian areas and the transliterated term *riparian zone*. Students first discuss the local term in their own language, grounding the concept in familiar ecological knowledge. The teacher then presents the transliterated term, showing how it connects to regional and global scientific discourse. By using both, students build ecological understanding while gaining academic vocabulary, strengthening confidence in their mother tongue alongside preparation for higher education.

Within ethnotranslation, retaining robust local terms is paramount. Transliteration is most valuable when no equivalent exists, as it allows learners to engage with standardized scientific terminology while preserving linguistic integrity.

It also helps students transition into higher education by fostering familiarity with both their mother tongue and the dominant academic language. In this way, transliteration functions as a pedagogical bridge, advancing linguistic and educational equity for Indigenous and Creole learners.

At the same time, some communities may be cautious about adopting transliterated terms. For this reason, transliteration should be encouraged but never imposed; communities must retain full agency in deciding whether to incorporate such terms.

Information and Communication Technology (ICT) Translation as a Bounded Component of the Ethnotranslation Model

As Indigenous and minoritized languages continue to evolve, new lexical items will inevitably emerge, including terms that are not strictly scientific in origin but are nonetheless required for participation in contemporary social, institutional, and informational contexts. The development of such terms should be guided not only by linguistic accuracy but also by considerations of cognitive load and pedagogical efficiency. In some cases, neologisms generated through formal linguistic processes may result in expressions that are excessively long, difficult to pronounce, or cumbersome for routine use, thereby increasing cognitive load without corresponding conceptual benefit. In these instances, we recommend approaches similar to those described by Nelsy Rubí Cituk Poot (2015), a Maya woman and Maya-language scholar, whose research focuses specifically on neologism creation in Yucatec Maya within the ICT semantic field. Such strategies recognize that linguistic elegance and pedagogical effectiveness do not always align with maximal structural transparency, and that iterative refinement is both expected and desirable in living languages.

Within the *Ethnotranslation Model*, ICT-related neologism development follows a bounded, iterative procedure adapted from Cituk Poot's (2015) ICT-focused methodology.

This process begins with the identification of lexical gaps arising from everyday technological use, followed by the generation of candidate terms using internal morphological and semantic resources of Yucatec Maya. Candidate forms are evaluated not only for structural legitimacy but also for usability criteria, including length, pronounceability, and ease of incorporation into instructional and conversational contexts. Candidate terms are provisionally retained, revised, or discarded based on speaker consensus regarding communicative efficiency and perceived naturalness of use within ICT contexts. Where initial forms impose excessive cognitive or articulatory burden, iterative refinement is undertaken through consultation and community-based validation, allowing for simplification, semantic adjustment, or alternative constructions while preserving conceptual integrity. Acceptance is determined through collective speaker feedback rather than prescriptive standardization, ensuring that adopted terms reflect actual communicative preferences within the ICT domain as documented by Cituk Poot (2015).

By retaining Cituk Poot's methodology strictly within the ICT domain for which it was designed, the *Ethnotranslation Model* respects both methodological boundaries and Indigenous scholarly authorship, avoiding inappropriate extension of a domain-specific linguistic process into ecological and biological contexts where different knowledge relations and translation criteria apply.

Linguistic Provenance and the Treatment of Proper Nouns

A related consideration concerns the treatment of proper nouns. This project recommends that proper nouns be spelled according to the orthographic conventions of their language of origin, rather than being respelled to conform to the preferred orthography of a target or dominant language. The common practice in Western languages of altering the spelling of proper nouns (e.g., in English: Panamá is rendered as Panama, México is rendered as Mexico) provides little pedagogical benefit while potentially increasing cognitive load and diminishing respect for linguistic provenance.

Such practices are therefore discouraged within the *Ethnotranslation Model*. Maintaining original orthography for proper nouns supports linguistic integrity, reinforces cross-linguistic awareness, and better prepares learners to access global information systems without requiring unnecessary relearning or orthographic adjustment.

This principle also extends to institutional and organizational names, though with additional pedagogical caution. For example, the name of the research organization Marine Conservation without Borders is rendered in Yucatec Maya as *Kanan K'áak'náab Ma' Su'up'il*. According to personnel from the *Secretaría de Educación de Quintana Roo* (SEQ) participating in the project, this form proved difficult for many children to pronounce and increased cognitive load with little immediate instructional benefit. This observation underscores the importance of context-sensitive decision-making: while early exposure to properly rendered multilingual proper nouns can support long-term familiarity and prepare learners to navigate global information systems, such exposure must be developmentally appropriate and introduced gradually. Within the *Ethnotranslation Model*, fidelity to linguistic provenance is therefore balanced with learner readiness, ensuring that respect for linguistic plurality does not inadvertently impede comprehension or engagement.

BASE jumping [*Salto BASE*] illustrates the importance of engaging Indigenous and Creole knowledge keepers when working with specialized terminology. BASE jumping is a sport in which participants use parachutes to jump from fixed objects such as **B**uildings, **A**ntennae, **S**pans [bridges], and **E**arth objects [cliffs] (Boenish, 1984).

To illustrate the complexity of specialized language, consider a statement the researcher once made to fellow skydivers after a trip to West Virginia: *"It's an 8.8-second rock drop. I used a Hewitt rig and did a solid 7 before I dumped."*

To non-BASE jumpers, this statement would likely be opaque or even alarming, yet within the context of the sport it conveys specific technical information understood only by those fluent in that community's terminology.

- In BASE jumping vernacular, an **8.8-second rock drop** refers to the height of the New River Gorge Bridge in Fayetteville, West Virginia (approximately 876 feet or 267 meters). During the golden age of BASE jumping, participants lacked instruments capable of measuring such short freefall distances. To estimate height, BASE jumpers would drop a rock and count the seconds until impact, a simple yet remarkably consistent method for gauging distance.

- **Hewitt rig** specifies that the researchers BASE container was a Wizard designed by Mark Hewitt.

- **Solid 7** means seven full seconds of freefall before initiating the deployment sequence.

- **Dumped** denotes initiating deployment sequence less than two seconds prior to impact.

This example shows how specialized knowledge is densely encoded within community-specific language (Pierotti & Wildcat, 2000). In the same way, Kriol and Garifuna fishers use precise terms for seasonal currents, fish migration, or mangrove conditions, intelligible only to those immersed in those systems (Thigpen, 2025; Palacio, 2001). Similarly, Maya chicleros developed highly specific vocabularies for forest conditions, tree health, and resin flow, knowledge essential for sustainably harvesting *Manilkara zapota* latex (Rubin & Jones, 1944; Ticktin, T. (2004). Across both marine and terrestrial domains, such linguistic precision reflects ecological expertise embedded in lived experience.

Collaboration with native knowledge keepers is central to ethnotranslation, ensuring that educational materials reflect community cultural and ecological knowledge. These partnerships rely on dialogue and participatory engagement, where Indigenous experts contribute insights into ecological practice, cultural context, and language use. Evidence from the researchers' recent projects shows that when knowledge keepers are directly involved in curriculum development, students not only gain deeper environmental understanding but also strengthen their cultural identity (Thigpen 2025; Poot Cahun, 2025).

The Role of Binomial Nomenclature

A key aspect of ethnotranslation is incorporating binomial nomenclature into primary school materials. This Latinized system of naming species (Linnaeus, 1758) provides a universal reference for biodiversity. While Indigenous languages contain unique common names, aligning them with binomial nomenclature allows students to join global scientific conversations without losing connection to their linguistic heritage.

Teaching scientific names alongside local terms enables students to see classification in both scientific and Indigenous contexts. In this way, binomial nomenclature becomes a bridge between local ecological knowledge and formal biology, preparing Indigenous and Creole learners for advanced studies while preserving the integrity of their own linguistic and ecological classification systems.

For example, the collared peccary is *Kitam* (*Pecari tajacu*) in Yucatec Maya and *Pikayri* (*Pecari tajacu*) in Belizean Kriol. The Yucatan black howler monkey is *Ba'ats'* (*Alouatta pigra*) in Maya and *Baaboon* (*Alouatta pigra*) in Belizean Kriol. Such examples show how binomial nomenclature complements, rather than displaces culturally embedded taxonomies.

To help learners bridge these systems, prototype STEM Plus materials included an age-appropriate introduction to binomial nomenclature authored by Anna J. Phillips, Ph.D., of the Smithsonian's National Museum of Natural History. This integration of expert-authored content into locally adapted curricula highlights the collaborative nature of ethnotranslation.

In Belize, mangrove education materials were refined with direct input from Kriol and Mopán speakers, while in Quintana Roo, Maya knowledge keepers shaped biological terminology to reflect traditional ecosystem understandings. These collaborations demonstrate that Indigenous expertise is not supplementary but essential for creating effective, inclusive, and culturally resonant educational resources (Poot Cahun, 2025; Thigpen, 2025).

Results

Case Study: Maya Language Education in Quintana Roo, Mexico

A two-year case study in six Indigenous primary schools in the state of Quintana Roo, Mexico evaluated the impact of *ethnotranslated* biology materials in Maya Yucateco (Poot Cahun, 2025). Developed under the editorial guidance of Thigpen within the *STEM Plus* initiative, these materials drew on authors primarily from the *Global South* and were grounded in the *ethnotranslation* framework, *Biocultural Constants*, and the *Hybridization Hypothesis of Ecological Knowledge Systems* (Thigpen, 2025). In the final stage, two books were *ethnotranslated* into Yucatec Maya by Hilario Poot Cahun. Although not originally created for Quintana Roo, their successful use demonstrated the portability of both the methodology and its theoretical foundation. Early outcomes were first discussed in Thigpen (2025), which drew on multilingual mangrove prototypes as the basis for the Maya curriculum piloted here.

Fieldwork was conducted under a tripartite research agreement among Marine Conservation without Borders (MCB), *la Universidad Intercultural Maya de Quintana Roo* (UIMQROO), and the *Departamento de Educación Indígena de los Servicios Educativos de Quintana Roo* (SEQ). Thigpen served as project leader. As the implementing partner, MCB held responsibility for site access authorization and maintained a duty of care toward participating Indigenous primary school and university students, in accordance with its obligations under Mexican research agreements.

All data collected in this case study were used exclusively to support Hilario Poot Cahun's master's thesis project at UIMQROO and remain under his authorship and MCB's supervision.

The study found:

- Stronger cultural and linguistic identity, with students choosing to speak Maya at home (Poot Cahun, 2025).
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- Greater environmental awareness, including increased responsibility for waste reduction and conservation (Poot Cahun, 2025).
- Bilingual teaching adaptations, as educators adjusted strategies for varying levels of Maya and Spanish fluency (Poot Cahun, 2025).
- Higher student engagement, as learners connected more deeply with content reflecting their ecological and linguistic heritage (Poot Cahun, 2025).
- These findings parallel results from smaller-scale studies in Belize, where Kriol and Mopán materials likewise improved student engagement and comprehension (Thigpen, 2025).

The depth of this impact is best expressed in the words of a parent. A mother from La Esperanza reflected: “Well, after the classes my son started speaking Maya. It was strange because he usually spoke Spanish, but now he tells me not to speak to him in Spanish. ‘Speak to me in Maya,’ he says. If I speak to him in Spanish, he scolds me. He only wants me to speak to him in Maya.” (Anonymous parent, La Esperanza)

Hilario Poot Cahun’s thesis project directly reached 96 Maya students in Indigenous primary schools, along with their families, 12 Maya research assistants at UIMQROO, and 6 primary school teachers. These figures show both the scale of the pilot study and its intergenerational reach.

Findings from the Quintana Roo case study validate the *Ethnotranslation Model*. Culturally grounded education extended learning beyond the classroom, strengthening Maya language use at home and encouraging conservation behaviors such as waste reduction. Teachers adopted bilingual strategies to address fluency gaps, and overall engagement rose as students connected more deeply with content reflecting their ecological and linguistic heritage (Poot Cahun, 2025). These outcomes align with earlier results from Belizean classrooms (Thigpen, 2025).

Challenges and Institutional Dynamics

While the outcomes of this work have been positive, several challenges have accompanied its development and implementation.

Because the hybridized approach and the ethnotranslation model described here extends beyond current norms in curriculum design and linguistic education, it has at times been resisted by institutions and individuals accustomed to heritage-language frameworks or monolingual [dominant language] science education. My identity as a white researcher has also complicated institutional support, despite the fully collaborative, community-guided nature of the project.

Skepticism from some Western-trained linguists reflects how far the initiative lies outside the siloed traditions of cultural and linguistic studies, since the materials deliberately merge traditional ecological knowledge with heritage-language and curriculum development in ways that transcend disciplinary conventions. These tensions reflect broader structural barriers in postcolonial education and underscore the need for inclusive, cross-cultural coalitions in language revitalization and science education (Smith, 2012; Battiste, 2002; Brock-Utne, 2000).

The researcher’s academic training is in Applied Anthropology and Biology, rather than in linguistics or curriculum design. Although unconventional in these circles, this interdisciplinary background has proven advantageous. Less constrained by disciplinary assumptions embedded in Western linguistic and educational theory, he was able to practice relational learning and active listening within Indigenous and Creole communities, allowing their knowledge systems and educational priorities to guide the development process. This approach aligns with Indigenous research methodologies that emphasize relational accountability and community-guided knowledge production (Kovach, 2009). The *Ethnotranslation* model and hybridized curriculum described here did not emerge from abstract theorizing but from years of collaborative, community-directed problem-solving grounded in lived ecological knowledge and linguistic practice.

Another recurring challenge has been the tendency of external actors, most often from the United States and Europe, but also from Latin America and the Caribbean to misunderstand the nature of this work. Rather than engaging as participant-observers or collaborators, they approached the project through the lens of Western ideologies and disciplinary assumptions that are often incompatible with the project's community-grounded goals.

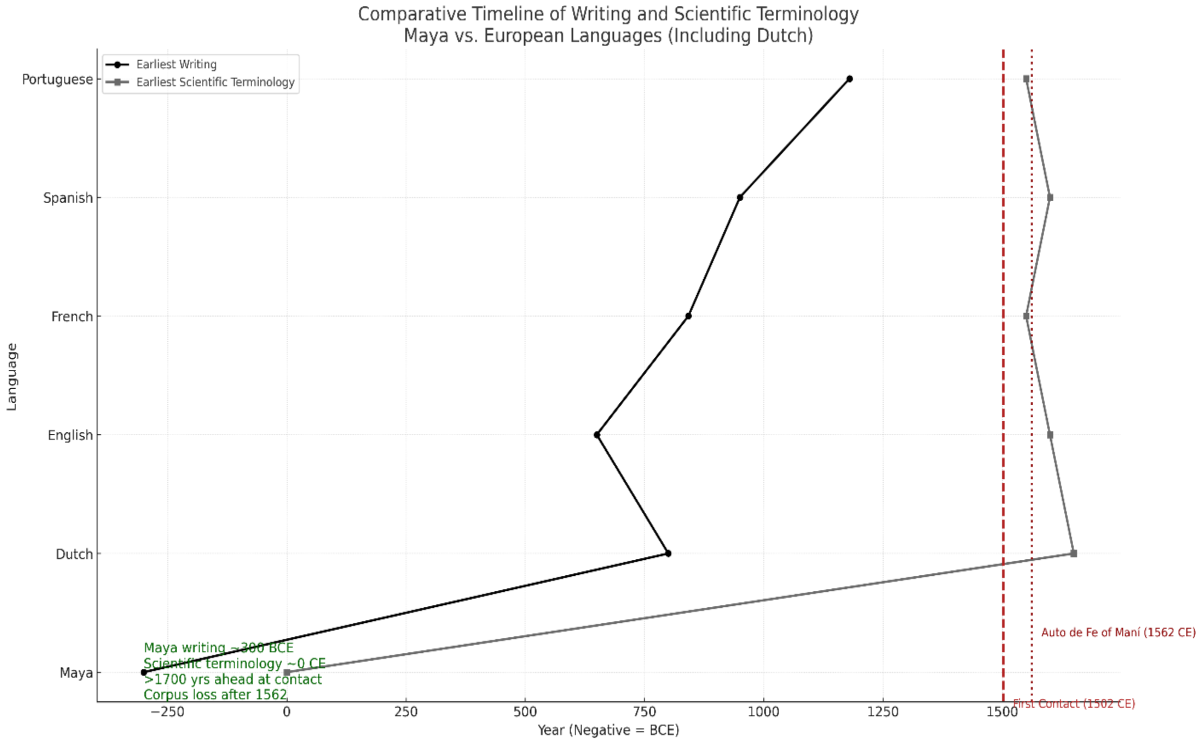
In several instances, the foundational premises of the work have been met not with curiosity but with resistance, expressed through a form of credentialist authority rooted more in academic status, whether achieved or aspirational, than in lived experience with community-based conservation or multilingual education.

In these moments, their actions fell outside the ethical principles of Indigenous and rights-based research, which require reciprocity, respect, and accountability to communities rather than credentialist self-assertion. Such dynamics illustrate a broader institutional pattern in which academic credentialism is privileged over experiential ecological knowledge, creating friction in the implementation of multilingual, rights-based approaches (Walsh, 2018). These dynamics have slowed progress and, at times, threatened to derail the project

Yet the goals of this initiative remain regional, grounded in lived realities, and shaped by sustained collaboration across Mesoamerica and the Caribbean. These patterns of interference underscore the urgent need for humility, reflexivity, and long-term relationship-building in multilingual, community-led education and conservation efforts. Through the challenges, it has been Indigenous and Creole educators, students, elders, and families who have most clearly understood the heart of this project. Their insight, friendship, and sustained support have enabled its continuation, even in the face of exhaustion and opposition.

Figure 1

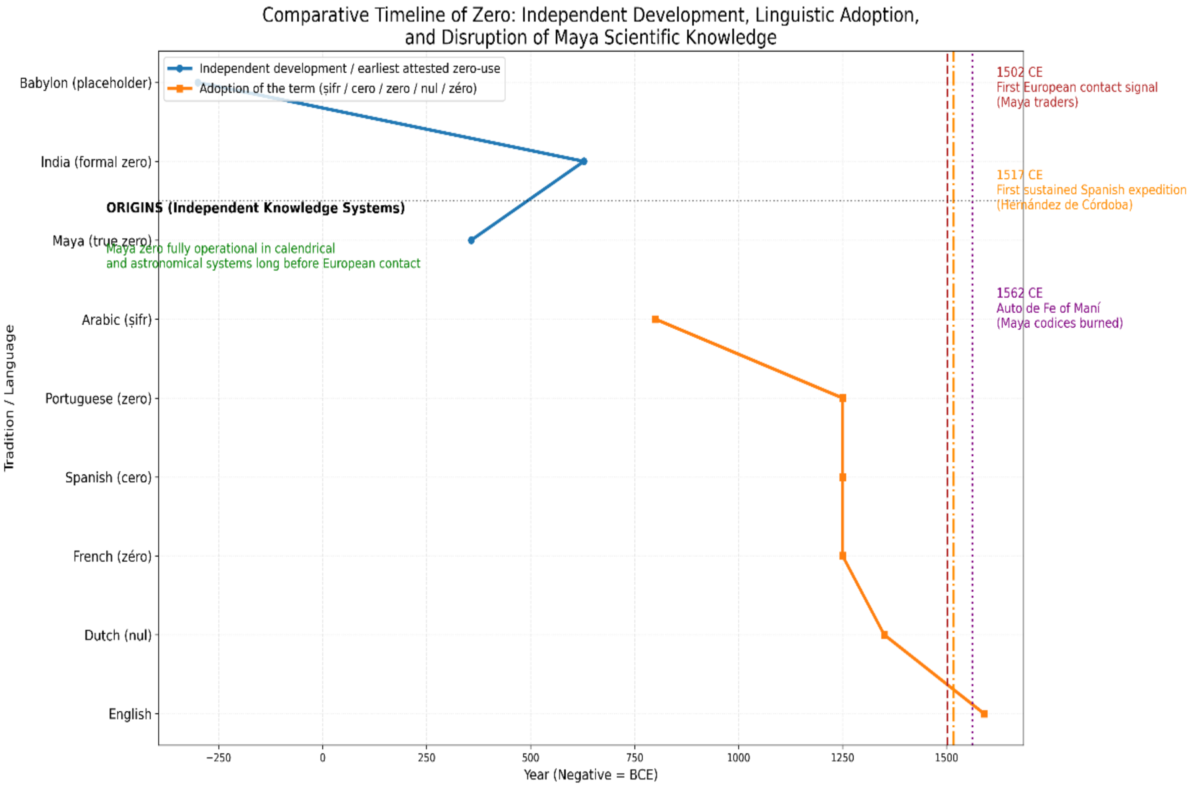
Comparative timeline of the earliest attested writing and earliest evidence of scientific terminology.



Comparative timeline of the earliest attested writing and earliest evidence of scientific terminology in Maya and major colonial European languages. Maya writing is dated to ca. 200–300 BCE with scientific vocabularies appearing by ~0 CE. European vernaculars including English, Dutch, French, Spanish, and Portuguese, enter writing between the 7th and 12th centuries CE, and do not develop standardized scientific registers until the early modern period. Vertical lines indicate Maya–European first contact in 1502 CE and the 1562 *auto de fe* of Maní, in which Diego de Landa burned Maya codices. By this time, Maya languages had accumulated more than 1,700 years of written scientific tradition.

Figure 2

The independent development of zero contrasted with later linguistic adoption.



The independent development of zero contrasted with later linguistic adoption of the term in Arabic and European languages. Independent origin systems (Babylonian, Maya, and Indian) are shown separately from language traditions to emphasize parallel, non-derivative knowledge systems. Vertical reference lines indicate key moments of European–Maya encounter and disruption: the first European contact signal via Maya traders (1502 CE), the first sustained Spanish expedition to the Yucatán (1517 CE), and the *Auto de Fe of Maní* (1562 CE), during which a substantial portion of the Maya written scientific corpus was destroyed. The figure highlights the asymmetry between European knowledge acquisition and the contemporaneous suppression of Indigenous science.

Table 1

Ecosystem using Transliteration or local Orthography.

Country	**Language**	**Ecosystem**
Belize	Kriol	Eekosistim
Belize	Mopán	pachkuxtal
Bonaire	Papimientu	ekosistemanan
Cameroon	Iyasa	bá emɛnɔ á bovíyá
Colombia	Wayuu	sukua´ipa mmapakat
Guatemala	Garifuna	ekosisütema
Guatamala	Q'eqchi'	li yoyookil xul ut yoyookil ha’
Haiti	Kreyòl Ayisyen	Ekosistèm
Honduras	Miskito	rayaka manis bara pliska
Indonesia	Bahasa	Ekosistem
México	Maya Yucateco	báak’pachkuxtal
Myanmar	Burmese	ဂေဟစနစ်
Nicaragua	Ulwa	dî sangkaka karak balna ûkana

Note: Translations and transliterations of the term *ecosystem* in selected Indigenous and Creole languages across multiple countries, used in the development of STEM Plus curricula.

Table 2.

Western Transliteration

Country	***Language***	***Ecosystem***
Brasil	Portuguese	ecossistema
France	French	écosystème
Germany	German	ökosystem
Netherlands	Danish	økosystem
Spain	Spanish	ecosistema
United Kingdom	English	ecosystem

Note: Translations of the term ecosystem in select Western languages.

Table 3.

Riparian Zone

Country	***Language***	***Riparian Zone***
Brasil	Portuguese	zona ribeirinha
France	French	zone riveraine
Germany	German	uferzone
Netherlands	Danish	oeverzone
Spain	Spanish	zona ribereña
United Kingdom	English	riparian zone
QROO	Maya	U jáal ja’

Note: The term riparian zone in selected Western languages and Maya Yucateco.

Discussion

Although this paper centers on Indigenous and Creole contexts, the implications are broader. Similar dynamics of disengagement, low retention, and cultural irrelevance also affect majority-language STEM classrooms.

Ethnotranslation and biocultural education therefore offer lessons for improving STEM education universally, even as they remain essential for equity in multilingual regions.

Afro-descendant ecological knowledge strengthens these conclusions. The ecological systems developed by Kriol, Garifuna, Jamaican, Surinamese, and Haitian communities include detailed knowledge of mangroves, reef ecology, tides, seasonal currents, cloud and weather interpretation, plant pharmacology, and agroforestry (Palacio, 2001; Price, 2013; Voeks & Rashford, 2013). These traditions, like Maya ecological knowledge, were transmitted through Afro-descendant and Indigenous languages that carried specialized scientific terminology. Their exclusion from science education reflects the same epistemological erasure that ethnotranslation is designed to address. Integrating Afro-descendant ecological knowledge within the STEM Plus model strengthens linguistic rights, broadens scientific understanding, and more accurately reflects the multicultural ecological expertise of the Wider Caribbean.

By embedding cultural relevance into ecological literacy, the *ethnotranslation* model advances a more just and resilient pedagogy. It enables STEM education that respects Indigenous and Creole knowledge systems, aligns with the *Hybridization Hypothesis* by integrating diverse ecological traditions into curricula, and extends Aikenhead's (2001) argument that science education must facilitate epistemological negotiation across cultural borders. In doing so, it fosters both environmental stewardship and linguistic revitalization, especially when grounded in participatory methods. This approach reaffirms the bridge-building metaphor at the core of the ethnotranslation model, demonstrating that students need not abandon one worldview to enter another; instead, they can stand securely on the epistemological bridge where ecological knowledge systems meet as coequal partners.

The *ethnotranslation model* validates Indigenous ecological knowledge systems and strengthens conservation, while also holding potential to operationalize rights frameworks such as UNDRIP and ICCLR. Transliteration provides linguistic familiarity without compromising scientific integrity.

Together, these elements set a precedent for participatory, rights-based curriculum development in multilingual and multicultural systems, offering a scalable framework for cross-linguistic adaptation through biocultural constants. In parallel, López-Maldonado *et al*., (2024) frames these linkages as Indigenous Science Diplomacy, highlighting how Indigenous observations and governance practices can [and should] inform science–policy interfaces, an aim ethnotranslation advances at the educational tier.

This project gives Indigenous and Creole languages an applied scientific and national value that traditional heritage studies and linguistics often do not. Conventional disciplines tend to treat these languages as cultural artifacts to be preserved, documented, or analyzed which is important work, but frequently symbolic in scope. In contrast, *Ethnotranslation Model* and the STEM Plus model operationalize these languages as epistemological technologies: systems through which ecological knowledge is generated, structured, transmitted, and applied. Rather than positioning them as objects of study, the project treats Indigenous and Creole languages as sophisticated knowledge architectures capable of expressing and advancing complex concepts in biology, ecology, engineering, and agroforestry.

This approach reframes these languages as educational, ecological, and developmental assets, not only for their communities of origin but for national education systems and global scientific efforts. In doing so, the project restores functional value to languages historically targeted by epistemicide, demonstrating their ongoing relevance to biodiversity conservation, community well-being, and global sustainability. It further shows that these languages are not remnants of the past but essential, contemporary tools needed for today’s environmental and educational challenges.

In this sense, ethnotranslation extends the lineage of global education policy, beginning with UNESCO's landmark 1953 monograph *The Use of Vernacular Languages in Education* (UNESCO, 1953).

Unlike conventional language-inclusion initiatives that focus on single linguistic communities, ethnotranslation emphasizes interoperability and scalability for all linguistic communities across shared ecological zones and species ranges. Policy implications include advancing language rights, enhancing biodiversity education, and meeting commitments under the Cartagena Convention and IUCN Target 20.

Although grounded in fieldwork across Latin America and the Caribbean, both the *Hybridization Hypothesis of Ecological Knowledge Systems* and the *ethnotranslation model* demonstrate global applicability. Each is anchored in universal principles, biocultural constants, linguistic equity, and participatory curriculum design that can be adapted across linguistic groups and ecological contexts worldwide. The outcomes documented in Quintana Roo, México (Poot Cahun, 2025) show that ethnotranslation is not only theoretically robust but also practically effective across multiple sites and languages.

These materials could also prepare students for meaningful roles in the Blue and Green Economies, including sustainable fisheries, conservation, ecotourism, and climate-resilient livelihoods. By grounding scientific instruction in local ecosystems and languages, students gain the competencies needed for sustainable resource management and economic resilience. Ethnotranslation-based education thus serves both as an academic intervention and a workforce development strategy aligned with regional and global sustainability goals.

Because *biocultural constants*, species, ecosystems, and ecological relationships are not confined by political borders, the *ethnotranslation* model is not geographically limited. It can be applied wherever multiple linguistic communities share a bioregion or species range, from the Caribbean to Appalachia to the Arctic tundra to Raja Ampat to sub-Saharan Africa to Tierra del Fuego. Originally developed for marine ecosystems in the greater Caribbean basin, the model was grounded in mangroves, reef species, and fishing traditions, making it naturally scalable across

CARICOM (the Caribbean Community) and Latin America. The same principles also extend to terrestrial systems rainforests, deserts, savannas, and highland agriculture where recurring ecological relationships intersect with linguistic and cultural diversity.

Scaling *STEM Plus* curricula across the greater Caribbean basin could transform both conservation and regional economies, as graduates carry integrated knowledge of science, language, and sustainability rooted in their own ecosystems and cosmologies. The broader vision of *Ethnotranslation* is not only pedagogical but also a foundation for lasting biocultural resilience. To the researcher's knowledge, aside from his own mangrove prototypes developed for every seafaring linguistic group of the western Caribbean, from the Yucatán Peninsula to Puerto Limón, Costa Rica and expanded to include Haitian Creole**,** Papiamentu (Bonaire), and Wayuunaiki (Colombia), as well as Bahasa (Indonesia) and Burmese (Myanmar), no comparable initiative has pursued systemic inclusion by creating ecologically grounded STEM materials that integrate science and language across multiple bioregions and cultural contexts. If implemented throughout the greater Caribbean basin, the model would set a global precedent for multilingual, rights-based science education.

Building on the Quintana Roo pilot, future efforts will expand the ethnotranslation model into new regions and languages. Its design enables materials to be localized across Indigenous and Creole communities within shared ecoregions, allowing regional implementation without losing cultural specificity. Planned collaborations include Ngäbe communities in Panamá, Wayuunaiki in Colombia, Miskito in Honduras, and Ulwa in Nicaragua, with curricula tailored to ecosystems such as mangroves, cloud forests, marine protected areas and local flora and fauna. These initiatives will also develop digital platforms, teacher recertification modules, and university coursework, ensuring continuity from early education through higher learning.

The 2023 Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (BBNJ Agreement) highlights the policy relevance of this model. As a legally binding treaty, the BBNJ calls for equitable benefit sharing, the protection and use of traditional knowledge

(Articles 7(j) and 13), and capacity building for developing and small island states (Articles 8 and 14).

Ethnotranslation directly advances these priorities by delivering place-based marine education in Indigenous languages, strengthening local governance capacity, and positioning Indigenous ecological knowledge systems as co-equal sources of ecological understanding within formal science education.

The next step is national-scale implementation: developing culturally grounded *STEM Plus* materials for every Indigenous and Creole linguistic group within a country. Nations with fewer than ten such communities, such as Belize, Honduras, Panamá, and Guyana are well positioned for early deployment. These efforts would provide a powerful demonstration of the model's feasibility and impact. To the researcher's knowledge, aside from the *Marine Conservation without Borders* mangrove prototypes developed for every linguistic community native to Belize, no initiative has attempted to create bio culturally grounded, multilingual STEM materials for every Indigenous and Creole linguistic community within a single nation. This level of ecological, linguistic, and curricular integration remains unprecedented in national education systems. Such national pilots could also serve as templates for regional and global replication, aligning education with biodiversity and language rights commitments. The long-term vision of ethnotranslation is to build durable bridges across ecological knowledge systems; bridges strong enough for future generations to stand on with confidence in both their cultural inheritance and their scientific future.

In addition to fostering early scientific literacy, the ethnotranslation approach supports long-term educational outcomes. By introducing standardized ecological terminology alongside local languages, the *ethnotranslation* model equips students with tools for a smoother transition into secondary and university education. This dual grounding enhances readiness for advanced STEM studies, where engagement with global scientific discourse is essential. Students become academically bilingual with ecological translanguaging skills and transknowledging skills, able to navigate both traditional ecological knowledge and formal science assets for higher education and emerging careers in conservation, education, and public policy (Thigpen, 2025).

Beyond academic progression, ethnotranslation also expands local employment opportunities for students who may not pursue university degrees. By rooting science in community languages and ecological knowledge, students gain practical skills relevant to conservation, resource management, ecotourism, and agroecology sectors where traditional ecological knowledge and cultural fluency are vital. Culturally grounded ecological literacy prepares them for meaningful roles as park rangers, tour guides, cultural educators, conservation assistants, and even principal investigators. These outcomes resonate with international frameworks such as the Cartagena Convention and the UNESCO Decade of Indigenous Languages, which emphasize integrating Indigenous knowledge and language into sustainability and education. As Crawhall (2007) notes, linking Indigenous knowledge to livelihoods and education is key to revitalizing cultural systems while preparing students for contemporary economic landscapes.

Originality and Global Comparison

These classroom pilots provided measurable evidence that ethnotranslation can be applied to multilingual science education and replicated across distinct cultural and linguistic contexts (Poot Cahun 2025).

Several projects worldwide integrate Indigenous ecological knowledge into science education, yet none replicate the complete configuration of the present initiative. In Canada, the *Two-Eyed Seeing* (*Etuaptmumk*) framework introduced by Mi'kmaq Elders Albert and Murdena Marshall and Professor Cheryl Bartlett (Bartlett et al., 2012) provides a respected model for bridging Indigenous and Western sciences. Likewise, Australia's *Two-Way Science* programme (Commonwealth Scientific and Industrial Research Organization [CSIRO], 2022) connects Aboriginal ecological knowledge and in-country learning with the national science curriculum. Both illustrate the power of epistemological pluralism in science education. However, these approaches typically operate within single language groups and emphasize conceptual integration rather than producing co-authored curricular materials adapted across multiple linguistic communities within a shared ecological basin.

Comparable efforts exist elsewhere. The *Nunavut Curriculum Framework* (Government of Nunavut, 2021) advances bilingual education in Inuktut and English through Inuit Qaujimajatuqangit, while New Zealand's reforms embed *Mātauranga Māori* within the science curriculum using dual-language resources (Ministry of Education [New Zealand], 2023).

Peru's *Educación Intercultural Bilingüe* (Ministerio de Educación del Perú, 2014) supports instruction in more than forty Indigenous languages, including science, yet remains largely confined to national language families.

The present project extends these precedents through two critical innovations. First, it introduces the *biocultural constants* framework, ecological relationships shared across linguistic and cultural boundaries and applies it to *STEM Plus* curriculum design in Belize and México. Each book is monolingual, written in the language of the intended community (for example, Yucatec Maya, Mopán, or Belizean Kriol), yet all follow a shared ecological and conceptual structure, enabling the same scientific content to be used simultaneously across multiple linguistic groups within one ecoregion. When requested, bilingual editions can be produced without altering the pedagogical or ecological foundations. This architecture allows new linguistic partners to adopt existing materials without starting from scratch, ensuring both efficiency and fidelity to local ecological knowledge systems.

Second, the materials are inherently interdisciplinary and policy-responsive. In Quintana Roo, the *Secretaría de Educación de Quintana Roo* (SEQ) requested to use the books for teaching reading and writing in Maya, recognizing their authenticity and linguistic rigor. The Belize *Ministry of Education, Culture, Science and Technology* (MoECST) has expressed interest in using the same series within their *Belizean Studies* program demonstrating that these materials can simultaneously support science, language, and social-studies curricula. This cross-disciplinary and cross-jurisdictional adaptability illustrates how *STEM Plus* content can meet local curricular needs while maintaining scientific precision and cultural integrity.

By 2024, the regional scalability and interdisciplinary value of the model were further demonstrated when the project's second monolingual Maya biocultural textbook developed through the same *Hybridization* and *Ethnotranslation* framework was adopted by three universities in two countries for use across distinct academic disciplines. The *University of Belize* incorporated the book into an online course titled *Conversational Maya*, designed to strengthen linguistic proficiency and cultural understanding.

The *Universidad Intercultural Maya de Quintana Roo (UIMQROO)* used the same text in its *Applied Linguistics* program to explore Indigenous language revitalization through science-based content. Meanwhile, the *Universidad para el Bienestar Benito Juárez García (UBBJ)* in Felipe Carrillo Puerto, Quintana Roo, employed the book to teach three sections of *Enseñanza y Aprendizaje de la Biología, Química, Biodiversidad y Desarrollo Sustentable* (Teaching and Learning Biology, Chemistry, Biodiversity, and Sustainable Development). Mayan student teachers at UBBJ subsequently applied these lessons during their practicum, teaching the materials in primary and secondary schools. Because Indigenous-language courses at the university level are generally confined to cultural studies, this represents so far as the researcher is aware the first documented instance of Maya being used as the language of instruction for university-level science courses.

Through iterative prototype, pilot, validation cycles, these community co-authored materials have been field-tested under formal partnerships with ministries and intercultural universities. The project reproduces the recognized benefits of intercultural education: identity affirmation, strengthened home-language use, and improved environmental learning while establishing a regionally portable, linguistically adaptable, and cross-disciplinary model that unites biodiversity education, language rights, and curriculum policy. To date, no other initiative globally combines these elements: a suite of monolingual, co-authored ecological books usable across multiple languages and disciplines within one ecoregion, validated in classrooms, and aligned with both national and Indigenous education systems.

Conclusion

This paper repositions Indigenous and Creole languages as legitimate vehicles for scientific inquiry. Grounded in the *Hybridization Hypothesis*, the *Ethnotranslation Model* shows how ecological understanding, linguistic revitalization, and cultural continuity can co-exist within rigorous STEM instruction. As López-Maldonado and Berkes (2017) demonstrate in the Yucatán Peninsula, cenote conservation can simultaneously revitalize culture and ecological governance.

More recently, López-Maldonado et al. (2024) show that Indigenous earth observations contribute directly to contemporary water-quality monitoring, broadening the epistemic reach of environmental science. The Quintana Roo pilot study demonstrated increased Mayan language use at home, stronger conservation behaviors, and higher classroom engagement, validating the success of the *Ethnotranslation Model* in community-guided, linguistically grounded education systems (Poot Cahun, 2025).

The *Ethnotranslation Model* is not only pedagogically sound but also politically and ecologically urgent. In the context of biodiversity collapse, climate disruption, and cultural homogenization, integrating traditional ecological knowledge into science education is a necessity. Scaled across the Caribbean and Mesoamerica, the *Ethnotranslation Model* could transform sectors from agroforestry to fisheries to tourism by preparing graduates who carry both scientific knowledge and cultural fluency into professional life. It is time to move beyond symbolic inclusion toward multilingual, place-based education systems co-created with communities. As Maffi and Loh (2017) emphasize, sustaining biodiversity requires sustaining the world's cultural and linguistic diversity; the ethnotranslation model operationalizes that principle through educational praxis that bridges scientific and Indigenous knowledge systems.

Everyone deserves a science education in the language they speak at home. This is not merely an ethical stance but a practical necessity for inclusive learning. The *Ethnotranslation Model* is replicable across disciplines, supporting linguistic equity and cultural relevance. By preparing students to engage with both traditional and global scientific knowledge, it strengthens cultural identity, ecological understanding, and academic progression.

Students acquire the skills and terminology needed to transition into higher STEM education, while non-university students gain ecological knowledge, cultural fluency, and tools for livelihoods in fishing, conservation, agriculture, ecotourism, and education. These outcomes align with UNESCO's Global Action Plan for the Decade of Indigenous Languages (2022–2032) and the Cartagena Convention, which call for linguistically grounded environmental education.

By equipping students with culturally rooted scientific literacy and practical skills, the *Ethnotranslation Model* prepares them for emerging sectors of the Blue and Green Economies.

It offers a pathway to local livelihoods and global engagement, reflecting a holistic vision that supports biodiversity, language vitality, and economic resilience. This vision builds on decades of recognition that education in Creole and Indigenous languages is essential, echoing UNESCO's (1953) call in *The Use of Vernacular Languages in Education* to make learning accessible in the languages students speak at home.

Although this paper focuses on Indigenous and Creole contexts, the implications are broader. The same dynamics of disengagement, poor retention, and cultural irrelevance affect majority-language STEM classrooms as well (Darling-Hammond et al., 2020; Osborne & Dillon, 2008). *Ethnotranslation* and biocultural education therefore offer insights for improving STEM education universally, even while they remain essential for equity in multilingual regions. Embedding cultural relevance into ecological literacy supports a more just and resilient educational paradigm, the central thesis of this work and a guiding principle for future biocultural education.

This relevance extends as well to Afro-descendant communities whose Creole and Afro-Indigenous languages preserve equally sophisticated ecological knowledge systems. Like Indigenous knowledge, these traditions were marginalized through colonialism and linguistic suppression as well as the transatlantic slave trade. Ethnotranslation provides a pathway for restoring their scientific legitimacy, ensuring that the full breadth of Abiayala and the Caribbean's biocultural knowledge, Indigenous and Afro-descendant can inform conservation, climate resilience, and education.

Ultimately, *Ethnotranslation* demonstrates that Indigenous and Creole languages are not relics of the past but vital scientific instruments whose value extends far beyond their communities to the nation and the world.

It shows that these languages function as essential, contemporary tools for addressing today's environmental and educational challenges, technologies capable of carrying complex scientific concepts, supporting climate resilience, and advancing biocultural sustainability. Rather than fading remnants, they are living systems of knowledge indispensable to biodiversity conservation, community well-being, and global ecological understanding.

In the end, this work is not extraordinary. It simply follows the lessons the researcher learned growing up: to listen closely, learn from the land and sea, and respect the ecological knowledge that lives within people and places.

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