Ethnobotany in science education: A pathway for biology teachers to engage with climate change and local knowledge

Fernanda Melo Gomes, Marina Sunshine S. L. dos Santos, Luiza Olívia Lacerda Ramos, Luisa Maria Diele Viegas

Correspondence

Fernanda Melo Gomes[1,2*], Marina Sunshine Souza Lobo dos Santos[1,2], Luiza Olívia Lacerda Ramos[2], Luisa Maria Diele Viegas[1,3]

[1]Laboratory of (Bio)Diversity in the Anthropocene, Federal University of Bahia, Salvador, Bahia, Brazil.
[2]Biology Institute, Federal University of Bahia, Salvador, Bahia, Brazil.
[3]Department of Biology, University of Mississippi, Oxford, Mississippi, United States.

*Corresponding Author: fermelogomes@gmail.com

Ethnobotany Research and Applications 34:12 (2026) - http://dx.doi.org/10.32859/era.34.12.1-13
Manuscript received: 07/11/2025 - Revised manuscript received: 09/04/2026 - Published: 11/04/2026

Research

Abstract

Background: Ethnobotany is an essential science for biocultural conservation and climate resilience, helping explain human-plant relationships in socio-ecological contexts. However, integrating Local Ecological Knowledge (LEK) and climate change into science education remains challenging in schools serving traditional and socially vulnerable communities, due to curricular rigidity, limited resources, and disconnection between curricula and local realities. This study investigates how Brazilian Biology teachers navigate these barriers in their pedagogical practices.

Methods: Using mixed methods, we conducted semi-structured questionnaires and interviews with Biology teachers from eight public schools across Brazil's North, Northeast, and South regions, selected for socio-environmental vulnerability and proximity to traditional communities. Analysis included thematic coding, descriptive statistics, Spearman's correlations (ethnobotany inclusion × teacher self-efficacy), and Fisher's exact test for regional Didactic Sequences (DS) adoption patterns.

Results: While 92% of teachers acknowledge ethnobotany's relevance, implementation revealed structural gaps. Curricula prioritized curriculum-based botanical content (morphology: 64%; reproduction: 55%) over LEK-related themes (medicinal plants: 36%; Unconventional Food Plants: 27%). Climate change education relied predominantly on expository methods (78%), with place-based strategies being marginal. DS adoption was low, with no significant regional association ($p = 0.776$). Three barriers were identified: 1) disconnection between curricula and community knowledge, 2) lack of contextualized materials, and 3) structural constraints in teacher training.

Conclusions: Despite barriers, pedagogical resilience emerged through school gardens, community-based projects, and locally adapted DS. We recommend co-developing materials with communities strengthening teacher training through intercultural and place-based approaches and building collaborative networks between schools and universities to embed ethnobotany and climate justice within science curricula.

Keywords: Brazil; Biology teaching; Climate crisis; Local Ecological Knowledge, Vulnerable communities

Background

Ethnobotany, as a branch of ethnoscience, studies the diverse interactions between humans and plants and is considered fundamental to both scientific advancement and biocultural conservation (Rocha *et al.* 2015). This discipline contributes to investigating and understanding the use of medicinal plants, dietary patterns, religious rites, and cultural practices (Franco *et al.* 2011), while positioning local communities as key agents of environmental stewardship. These communities are holders of Local Ecological Knowledge (LEK), defined as a dynamic and cumulative system of knowledge, practices, and beliefs regarding the relationships between local populations and their natural environment, developed through long-term ecological adaptation (Berkes 2012). In Brazil, LEK has been documented across quilombola, riverine, and other traditional communities, encompassing plant use practices transmitted across generations (Conde *et al*. 2017). Through LEK, communities offer critical contributions to addressing global challenges including climate change, food security, and biodiversity conservation (Reyes-García *et al.* 2019).

LEK, however, is increasingly at risk. Externally, anthropogenic pressures, including deforestation, accelerated species loss, and agricultural expansion, erode the ecological foundations on which this knowledge is built (Kungu 2025, Wanjohi *et al.* 2020). Internally, intergenerational transmission is declining, particularly for medicinal and nutritional plant uses, as younger generations may not fully acquire or value local practices (Mota *et al.* 2023). This erosion is further compounded by the marginalization of LEK within dominant knowledge models disconnected from local communities (McAlvay *et al.* 2023). Climate change intensifies this scenario with rising temperatures, reduced rainfall, and altered ecological cycles and plant communities in ways that directly impact ecosystems and the human populations that depend on them (IPCC 2022, Parmesan & Hanley 2015). Globally, traditional and local communities are recognized as being disproportionately affected by climate disruptions, facing prolonged droughts, floods, biodiversity loss, and food insecurity (Iocca & Fidélis, 2023). These groups, whose ways of life are intrinsically linked to the environment, are simultaneously the most affected by climate disruptions and the custodians of adaptive knowledge essential for socio-environmental resilience (Reyes-García *et al.* 2019).

Over the last decade, research has increasingly recognized ethnobotany as a framework for addressing challenges such as biodiversity conservation and the preservation of traditional plant knowledge in formal education (Marsandi *et al.* 2025, Brondizio *et al.* 2021). Schools in vulnerable contexts can serve as strategic spaces for valorizing LEK and promoting critical, intercultural science education (Reyes-García *et al.* 2010). However, this integration requires overcoming deep epistemological divides: school curricula typically privilege Western scientific knowledge, often representing indigenous and local knowledge as inferior or supplementary (da Silva *et al.* 2023).A critical intercultural approach reframes this relationship, treating LEK as a legitimate way of knowing and making explicit how different knowledge systems are produced, validated, and mobilized in context (El-Hani & Ludwig 2025; Robles-Piñeros *et al*. 2020). In practice, this means building bridges rather than hierarchies, acknowledging that students living in traditional territories often already hold ecological knowledge that can anchor, deepen, and humanize science learning.

Multiple studies suggest that integrating traditional practices into school curricula enhances local well-being and biocultural preservation while inspiring sustainable resource management (McCarter & Gavin 2011). By guiding students about the use and stewardship of native flora, such approaches maintain connections to local environments and honor ancestral community wisdom (Marsandi *et al.* 2025). Within this context, Didactic Sequences (DS) stand out as organized pedagogical pathways that prioritize students' prior knowledge and support interdisciplinary, place-based teaching (Santos & Cavalcanti, 2022, Souza & Machado, 2018). Defined as "ordered activities articulated around educational objectives, with clear starting and ending points known to both teachers and students" (Zabala 1998), DS enable teachers to create a bridge between scientific knowledge and traditional practices. Also, because DS are anchored in students' own cultural and ecological surroundings, they offer particular potential for integrating complex and locally grounded themes, such as ethnobotany and climate change, into science education.

Despite the transformative potential of ethnobotany as a pedagogical perspective, initiatives integrating it into basic education remain scarce, particularly in schools serving traditional communities (Silva & Albuquerque 2023). Compounding this gap is the urgent need to prepare new generations to understand and respond to climate change, a topic that UNESCO identifies as a priority for education and youth engagement worldwide (UNESCO 2021). This study investigates how Biology teachers working in traditional and/or socially vulnerable communities in Brazil integrate ethnobotanical knowledge and the climate crisis into their pedagogical practices. Because socio-environmental conditions, biomes, and local plant use vary across Brazilian territory, we adopted a multi-regional design including schools in the North, Northeast and South, not as a statistically representative regional comparison, but as an exploratory lens to situate teachers' practices across contrasting territorial contexts. We ground this research on the understanding that integrating ethnobotany and climate change into

school curricula strengthens biocultural resilience (Gaoue *et al.* 2017), empowers students to confront contemporary environmental challenges (McCarter & Gavin 2011), and promotes inclusive science education (da Silva *et al.* 2023).

Materials and Methods

Study context and participants

This mixed-methods study combined descriptive and interpretative approaches to understand how Biology teachers in traditional and socially vulnerable Brazilian communities integrate ethnobotanical knowledge and climate change into their pedagogical practices.

In this study, we use "traditional communities" following Brazil's National Policy for the Sustainable Development of Traditional Peoples and Communities (PNPCT; Decree No. 6.040/2007), which defines them as culturally differentiated groups that self-identify as such, have their own forms of social organization, and occupy/use territories and natural resources to sustain their cultural and socioeconomic reproduction (Brazil 2007). Recent scholarship highlights the socioterritorial and rights-based nature of this category and its relevance for understanding recognition and territorial relations in Brazil (Lima & Fiori 2023; Vorpagel & Cousin 2024). In this context, we use "social vulnerability" to describe a multidimensional condition shaped by structural inequalities that increases exposure to socio-environmental risks and limits people's capacity to cope with and recover from impacts (Biswas 2023).

Conducted between March 2024 and February 2025, the research focused on eight public schools across Brazil's North, Northeast, and South regions, selected for their socio-environmental vulnerability and located in or near traditional communities (Fig. 1).

School selection criteria included: (i) public schools located within traditional territories (e.g., an Indigenous school within the community) and/or serving students from traditional communities (e.g., quilombola, Indigenous, riverine, and other rural settlements); (ii) location in territories marked by socio-environmental vulnerability, including peripheral urban areas with historically limited access to public services and where schools serve predominantly low-income populations; (iii) feasibility of access and local authorization through existing institutional and community contacts; and (iv) teachers' willingness to participate. Not all schools met all criteria, rather, each participating site met a subset of these criteria, reflecting the diversity of territorial and socio-educational contexts included in the study (Fig.2).

We included schools from the North, Northeast, and South to capture variation across distinct socio-environmental contexts and to identify convergent barriers reported by teachers working under different territorial conditions, rather than to produce a statistically representative regional comparison. This multi-regional design also allowed us to consider contrasting biomes and floristic contexts, supporting an exploratory assessment of how locally used plants and ethnobotanical references appear in teaching practices across territories. Across sites, schools served communities characterized by strong place-based livelihoods and close relationships with local ecosystems, in settings where climate impacts and land-use pressures are salient to everyday life.

Access to participants followed a dual consent process. At each location, we contacted the leaders of the participating schools to request permission to interview their teaching staff. Participants included 13 Biology teachers at the upper secondary (high school) level (seven women, six men; aged 24-62 years) from schools serving traditional communities marked by socio-environmental vulnerabilities. Only for the analysis of Didactic Sequences (DS) adoption, two participants were excluded due to incomplete responses, resulting in a subsample of n=11 (Table 1). The sample represented varied regional contexts where ethnobotanical knowledge and climate change impacts are particularly relevant to local livelihoods.

Data collection

Data were collected in two steps (Alexiades 1996). First, participants completed a semi-structured questionnaire composed of 24 items (16 closed-ended, eight open-ended) organized into four thematic blocks: 1) teaching of Botany and use of traditional plant knowledge; 2) inclusion of climate change topics in the classroom; 3) evaluation of teaching materials; and 4) understanding and use of didactic sequences. Before DS-related questions, we provided participants with a brief definition of Didactic Sequences based on Zabala (1998) (i.e., an ordered set of activities organized around clear learning objectives, with defined beginning and end points). Follow-up questions were used to confirm that participants' answers referred to this pedagogical concept. Second, semi-structured follow-up interviews were conducted to explore emergent themes through conversational prompts (e.g., "Could you share a classroom example of bridging textbook content with local plant knowledge?"). The interviews ranged from 45 to 90 minutes, with an average duration of 58 minutes. All sessions were

audio-recorded with consent and supplemented by field notes documenting environmental context, non-verbal cues, and spontaneous references to local flora.

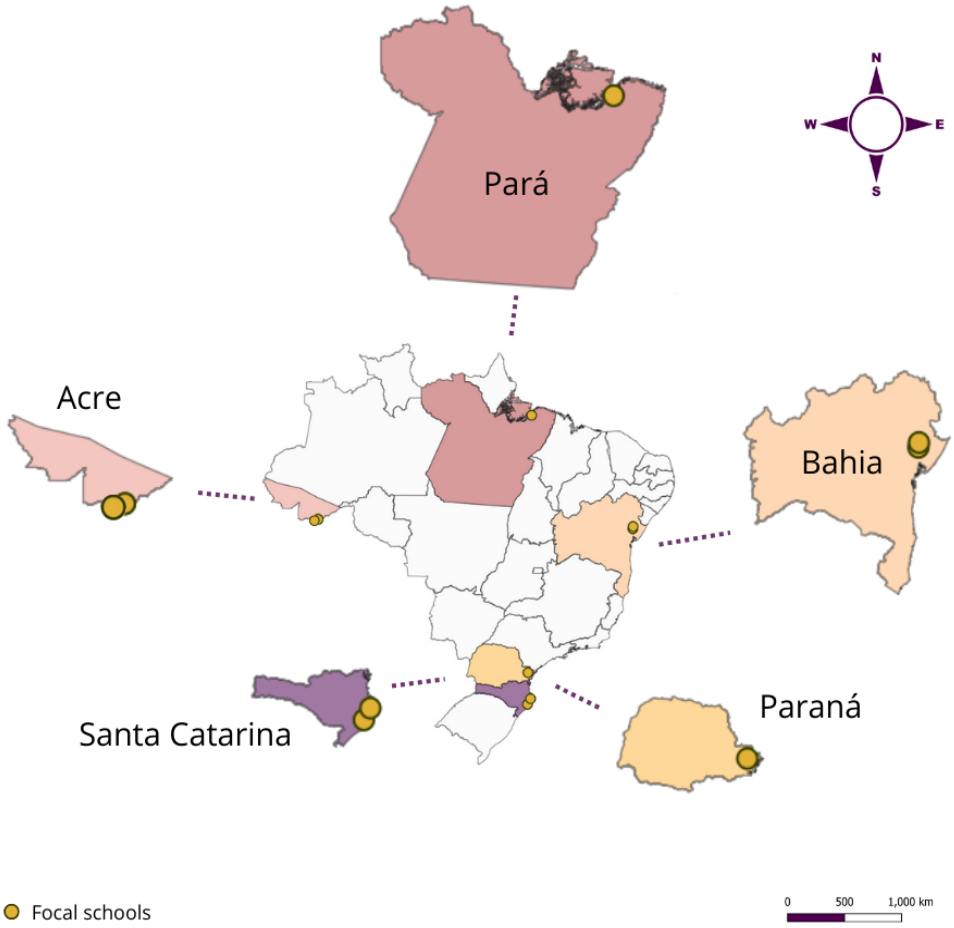

Figure 1. Geographic distribution of the eight public schools participating in the study. Each yellow dot marks a school located in or near traditional and socially vulnerable communities. The colored states (Pará, Acre, Bahia, Paraná, and Santa Catarina) indicate the five federative units where data were collected, highlighting the study's broad territorial reach across both northern and southern Brazil and its engagement with diverse socio-environmental contexts.

Data analysis

We employed a hybrid analytical approach integrating qualitative and quantitative methods. Qualitative data underwent thematic content analysis following Bardin's (2011) framework, using an indicative coding process to identify emergent categories from interview transcripts and open-ended questionnaire responses. Concurrently, quantitative analysis involved calculating frequency and correlations for closed-ended responses, with key variables including ethnobotany inclusion rates in lesson plans and teacher self-efficacy in climate change education. Descriptive statistics characterized distributions for botanical teaching themes (Fig. 2), climate change strategies (Table 1), and adoption rates of Didactic Sequences. Spearman's rank correlation coefficient (ρ) was applied to assess relationships between continuous variables, specifically between ethnobotany inclusion frequency and teacher self-efficacy scores, accounting for non-parametric data distribution. Regional variations in DS adoption were examined using Fisher's exact test with a significance threshold of $\alpha = 0.05$. Methodological triangulation was systematically implemented through cross-validation, whereby qualitative themes (e.g., "curricular disconnects") were interpreted against quantitative patterns (e.g., low ethnobotany frequencies). Finally, we contextualized the results in relation to existing literature on science education and biocultural conservation, highlighting consistencies and novel insights emerging from the data (Fig. 3). All quantitative analyses were performed using R 4.3.3 (R Core Team, 2024).

To assess the association between geographic region (North, Northeast, South) and Didactic Sequences (DSs) use, we initially applied Pearson's chi-square test. However, verification of the assumptions revealed that more than 20% of cells in the

contingency table had expected values below 5, violating test assumptions. We therefore adopted Fisher's exact test, appropriate for small samples and unbalanced distributions. Analyses were performed in R software (R Core Team, 2024), using the fisher.test() function from the stats package, with a significance level of α = 0.05.

Figure 2. Selected photographs of participating schools and their surrounding environments, illustrating the diversity of territorial and socio-environmental contexts encountered during fieldwork. (A) Federal Institute of Education, Science and Technology campus Ananindeua surrounded by Amazonian vegetation — Belém, Pará (North). (B) Community housing in the vicinity of the participating schools, reflecting conditions of social and climatic vulnerability characteristic of the territories served — Brasiléia, Acre (North). (C) River channel near the participating schools, with exposed and eroded banks; the absence of riparian vegetation has intensified recurrent flooding events that directly affect the lives of students and their families — Brasiléia, Acre (North). (D) Hand-painted entrance sign of the medicinal garden — Indigenous School, Imaruí, Santa Catarina (South). (E) Rural public school and surrounding Atlantic Forest vegetation in the interior of Paraná state — South Brazil. (F) Quilombola Community Association Curral de Fora, whose members attend the participating state school — Água Fria, Bahia (Northeast).

Results

Teachers' perceptions on botany teaching

Teachers most frequently referred to botany teaching through topics commonly addressed in school curricula and textbooks. The themes cited more often were plant morphology (64%), reproduction (55%), and plant ecology (46%) (Figure 3). In many accounts, these topics were mentioned in broad terms, often reflecting limited curricular time to deepen botany related content.

References connected to locally used plants and community practices appeared less frequently. Teachers mentioned medicinal plants (36%), Unconventional Food Plants (UFPs, 27%), phytotherapy (18%), and symbolic plant uses (18%), usually in relation to personal experiences, students' questions, or examples drawn from the surrounding territory.

In the thematic organization of data (Fig. 3), we chose to represent "medicinal plants" and "phytotherapy" as separate categories to reflect how teachers referred to them during interviews. These themes, along with UFPs and symbolic uses, are grouped in Figure 3 under the label "ancestral knowledge", used there as a visual shorthand for LEK-related content, as defined in this study. The term "medicinal plants" appeared more frequently in contexts related to popular and community use, while "phytotherapy" was associated with more systematic practices, often linked to formal health content and Integrative and Complementary Health Practices (PICS - *Práticas Integrativas e Complementares em Saúde*). PICS refers to Brazil's national policy for incorporation of evidence-based traditional/complementary therapies into the Unified Health System (SUS - *Sistema Único de Saúde*), institutionalized through Ordinance No. 971/2006 (Tesser et al. 2018).

Notably, 13% of teachers reported excluding botanical themes, prioritizing fauna-related content due to students' stronger identification with animals or curriculum time constraints: "They're more interested in animals, so I postpone plant content or never properly address it." (P6-Northeast).

Furthermore, although many teachers recognized the value of local knowledge, they face difficulties in weaving it into their pedagogical planning. Many reported difficulties bringing LEK into their classes, whether due to the absence of institutional support or the lack of adequate teaching materials. This distance between what students know and experience and what is formally presented in the classroom was identified as one of the main weaknesses in botany teaching.

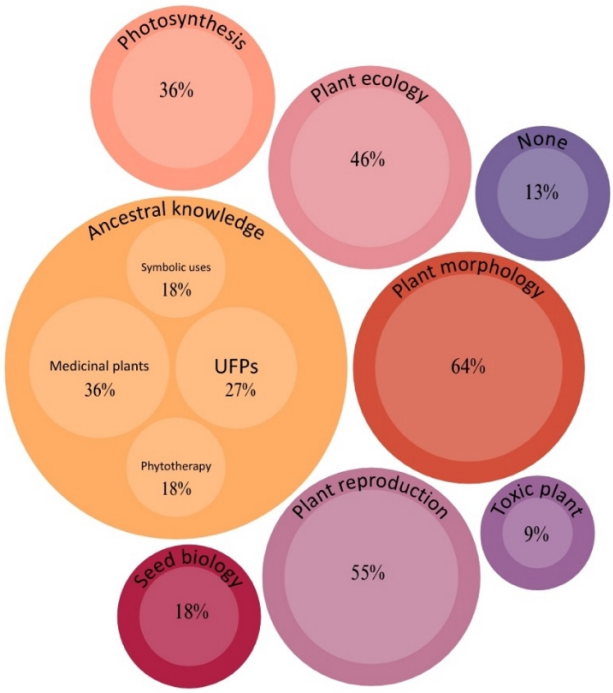

Figure 3. Major botanical teaching themes cited by Biology teachers. Themes related to locally used plants and community practices were grouped together as "ancestral knowledge" in the figure, used as a visual shorthand for LEK-related content, include medicinal plants, Unconventional Food Plants (UFPs), phytotherapy, and symbolic uses. The figure highlights the contrast between curriculum-based botanical content and LEK-related themes in teachers' reported practices.

Strategies for addressing climate change in basic education

Most teachers stated that they bring up climate change in the classroom, often associated with ecology content. These conversations usually arise in response to recent climatic events, such as droughts or floods, or during dialogues on sustainability and environmental preservation. The most frequently mentioned strategies for working with the topic were expository classes (78%), showing videos and documentaries (64%), and in-class discussions based on current news (55%) (Table 1). Practices with greater integrative potential were cited by a minority of teachers and included interdisciplinary projects, school gardens, field visits, and community workshops. These experiential activities are generally limited to individual teacher initiatives or extracurricular moments, without systematic institutional support.

Some teachers reported using external resources, such as newspaper articles, educational videos, and documentaries to complement textbook content, which, according to them, is insufficient to contextualize local realities. The integration of field practices, such as visits to native vegetation, was also mentioned, although in a rather unsystematic manner: "After presenting about the Plant Kingdom, I ask how students use plants, and which ones they already know. I also hold discussions and ask why certain specific plants existed and are no longer present today. I also bring up questions such as what is the relationship between the best-conserved vegetation areas and climate change, talking about irregular rainfall, etc" (P7-Northeast).

Table 1. Strategies adopted by biology teachers to address climate change in traditional and vulnerable communities.

Strategy	Description	Frequency of Citation (%)	Most Cited Region
Expository Lectures in Ecology-Related Topics	Discussions about climate change integrated into biology classes covering ecological content.	78%	North and Northeast
Use of External Materials	Use of videos, documentaries, and newspaper articles to contextualize the topic.	64%	Northeast and South
School Garden Activities	Practical activities in gardens to demonstrate climate effects on cultivation and sustainability.	45%	North
Field Trips and Ecological Trails	Visits to native vegetation for observing environmental impacts.	36%	North and South
Community Projects	Partnerships with local communities to study climate effects and adaptive solutions.	27%	Northeast
Debates and Conversation Circles	Group discussions about the effects of climate change on communities.	18%	Northeast

Despite their interest in exploring the topic more deeply, many teachers highlighted the lack of specific training and pedagogical materials that contextualize climate change from a local perspective. This limitation directly impacts the ability to build bridges between scientific knowledge and community-based knowledge, restricting the development of a critical perspective on the effects of climate change in the territories where students live.

Use of teaching materials and relationship with territory

The interviewed teachers almost unanimously indicated that available teaching materials, especially textbooks used in classrooms, are insufficient to promote contextualized approaches to botany, ethnobotany, and climate change. The main criticism lies in the generic character of the content, which rarely connects with the realities of traditional communities or socio-environmentally vulnerable territories. Many teachers stated that these materials neglect local cultural, ecological, and economic contexts, resulting in an education that is distant from students' lives.

In this sense, the challenge identified by teachers lies in how to teach botany, climate change, and ethnobotany in schools where textbooks often overlook the very plants, stories, and memories of the communities. In response, some teachers develop their approaches by creating alternative materials, using videos/documentaries, or even building school gardens. For example, a teacher highlighted the attempt to bring content closer to students' reality through contextualized practices: “We created a school garden with another teacher, so students could study botany with what they already know and plant in their community” (P8-South).

Another teacher exemplified interdisciplinarity by integrating traditional knowledge with natural and exact sciences content: “I like to bring recipes with plants and relate geography teaching by commenting on the origin of some plants; I discuss measurements used in recipes, besides chemical reactions. I mention, for example, that for plant cassava, soil correction with limestone is needed, thus already addressing some botany and chemistry” (P7-Northeast). Although promising, these practices remain sporadic and depend on individual teachers' initiative and availability, lacking clear institutional incentives for systematic adoption.

Understanding and use of Didactic Sequences (DSs) as a pedagogical resource

The questionnaire revealed that, although half of the teachers demonstrate familiarity with the concept of Didactics Sequences (DSs), few use this approach regularly in their pedagogical practices. In this study, “familiarity” refers to teachers’ self-reported recognition of the concept after the definition provided in the questionnaire, whereas “regular use” was assessed through a frequency item asking how often DSs were incorporated into planning. Some teachers reported being familiar with DSs but choosing not to use the approach in their practice. Among those reporting its use, most adopt pre-existing models and reported difficulty in crafting original proposals that integrate local knowledge, ethnobotany, and complex themes such as climate change.

In practice, teachers who used DSs described them to organize lessons in sequenced steps (e.g., starting from students’ prior knowledge, developing activities, and ending with synthesis/assessment), often to support interdisciplinary work and connect curricular content to everyday contexts. Qualitative data suggested contextual differences regarding regional aspects. Teachers from the South reported using DS in community projects like peasant fairs (i.e. spaces where family farmers and peasants sell their products directly, such as fresh and processed foods, promoting family farming and food security) and extracurricular activities (e.g., science clubs). Teachers from the Northeast, however, associated DS with integrated curricular strategies (e.g., soil correction in cassava cultivation with chemical and biological approaches).

By region, DS use was reported by 40.0% of teachers in the North (2/5), 66.7% in the Northeast (2/3), and 33.3% in the South (1/3). Statistical analysis showed no significant association between region and DS use ($p = 0.776$). Furthermore, factors such as teacher training and access to pedagogical resources appear to influence DS adoption more than geographic location.

Discussion

This study identifies three interconnected challenges in integrating traditional knowledge into science education in Brazilian contexts, supported by empirical evidence and theoretical literature: the gap in Local Ecological Knowledge, structural constraints in teacher training, and a lack of contextualized materials.

Local knowledge gap

Our results highlight that teachers deeply value LEK but struggle to weave it into their planning due to rigid curricula, reinforcing the need to bridge academic science and local ways of knowing (Albuquerque & Hanazaki 2009). However, ethnobiology studies show that the real challenge is not the absence of LEK but translating it into feasible classroom activities. When teaching is built from what students already know and experience in their territory, using locally relevant plants, LEK can become a concrete didactic resource rather than an “extra topic” added to the curriculum (Júnior 2020; Rico Lenta *et al*. 2023). The erosion of ethnobotanical knowledge weakens socio-ecological resilience (Brondizio *et al.* 2021), a risk aggravated by the absence of this knowledge in curricula.

While schools in biocultural hotspots are natural sites for sustaining traditional knowledge (Reyes-García *et al.* 2007), most curricula remain disconnected from student’s lived contexts (Júnior 2020). Studies in other biocultural regions show that teachers themselves may hold very different levels of knowledge about locally used plants, which shapes what is brought into classroom practice (Ladio & Molares 2013). Recent research in Brazil confirms that when traditional knowledge is systematically excluded from curricula, it undermines both cultural diversity and students' environmental engagement

(Oliveira & Miranda 2024). Yet, there are examples of successful integration, such as increased cultural transmission and biodiversity awareness among students who engage with local restinga plants (Van Luijk *et al.* 2021).

Structural constraints in teacher training

Teachers reported feeling underprepared to design interdisciplinary and contextually relevant lessons that incorporate local flora or climate issues, highlighting major obstacles such as inadequate teacher training and weak institutional support (Foss & Ko 2019). Similar challenges have been described by life sciences teachers, who struggle to integrate Indigenous and local knowledge meaningfully without proper training or teaching resources (Mkhwebane 2024). In intercultural biology education, overcoming these constraints requires specific teacher competencies (including intercultural and communicative skills) and collaborative arrangements that support pedagogical translation between knowledge systems (Lezcano Acuña & Hilgert 2023).

Valuing local knowledge alone is not enough, and teachers also need targeted training and institutional support to translate it into effective pedagogical resources (Ladio & Molares 2013). Limited collaboration and institutional neglect can further hinder the integration of local knowledge and climate justice (Bascopé *et al.* 2025), especially in geographically isolated schools lacking support networks for experience and resource exchange. As recent studies show, the distance between rural schools and administrative centers significantly reduces access to educational resources (Bonilla-Mejía *et al.* 2024), compromising professional development and pedagogical innovation (Leach & Bradbury 2024). Moreover, an epistemological gap persists between the traditional knowledge teachers aim to incorporate and their academic training, leaving them in a professional limbo without bridges to connect these worlds.

This isolation, which is not just geographic, exacerbates professional vulnerability, particularly when addressing complex issues such as climate change. Many teachers avoid teaching such topics due to discomfort or perceived irrelevance (Ennes et al. 2021), a pattern echoed in our interviews. Concurrently, dependence on decontextualized textbooks persists, constraining the development of place-based resources and reinforcing a cycle that prioritizes generic content (Ige & Jita 2020). Collectively, these challenges reflect a sense of pedagogical solitude, a critical barrier to contextualizing climate and ethnobotanical education in marginalized settings (Hargreaves, 1994).

Lack of Contextualized Materials

Our qualitative analyses indicate that most teaching materials are generic and overlook LEK. When traditional knowledge is invisible in official content, it undermines cultural diversity and environmental engagement in schools (Oliveira & Miranda 2024). In this sense, some teachers interviewed in our study address this issue by utilizing agroforestry gardens or local ecological case studies. Such actions, integrating and teaching local plant knowledge, can place Indigenous schools as centers of cultural resilience (Campani 2024).

To address these gaps, we propose four evidence-based directions: 1) Co-develop didactic materials with local communities to foster local biodiversity transmission (Reyes-García *et al.* 2007); 2) Revamp teacher training to include intercultural methods (McCarter & Gavin 2011); 3) Form collaborative networks between educators, universities, and communities (Júnior 2020); 4) Weave ethnobotany, climate justice, and place-based education into the curriculum to increase engagement, identity, and stewardship (Yemini *et al.* 2025).

Didactic Sequences: Innovation and Engagement

The use of DS as a pedagogical framework can foster student agency through participatory design, regardless of teaching modalities and models (Silva *et al.* 2025, Souza *et al.* 2022). However, our study reveals that most teachers are unfamiliar with DS, and those who do employ them typically rely on rigid templates with minimal adaptation to local contexts or interdisciplinary themes such as ethnobotany and climate change. This pattern reflects the lack of training and institutional support for context sensitive pedagogical planning.

From the perspective of ethnobiology education, DS can offer a practical pathway to translate recognition of LEK into structured classroom practice, especially when activities are adapted to sociocultural realities and involve locally relevant plants and daily practices (Rico Lenta et al. 2023). Place-based education research similarly emphasizes that structured pedagogical pathways become meaningful when grounded in local contexts and supported by adequate resources and teacher preparation (Yemini *et al*. 2025; Mkhwebane 2024).

The regional variation we observed in how teachers described DS use (e.g., community-oriented projects linked to food sovereignty in South, and integrated curricular strategies around agroecological practices in the Northeast) appears to reflect differences in implementation contexts and available institutional support, rather than region as a determining factor. Consistent with this interpretation, our quantitative analysis did not indicate a significant association between region and DS use. What these regional differences do reveal, however, is that culturally specific entry points, such as cassava cultivation in Northeastern territories, forest plant use in Amazonian contexts, or food sovereignty practices in the South, can serve as concrete anchors for DS design. Recognizing and building on these entry points is what transforms DS from a generic pedagogical template into a meaningful tool for biocultural education, one that connects scientific content to the ecological and cultural realities students already inhabit.

Conclusion

This study highlights the challenges and transformative potentials experienced by Biology teachers working in public schools located in Brazilian traditional and socio-environmentally vulnerable communities. While most educators recognize the pedagogical importance of ethnobotanical knowledge and climate change themes, they face multiple barriers that range from insufficient training and decontextualized materials to a profound lack of institutional support. Despite these constraints, our research reveals clear signs of pedagogical resilience: school gardens, agroforestry practices, community-based projects, and locally adapted Didactic Sequences demonstrate that teachers are actively seeking to connect scientific content to the ecological and cultural realities of their students' territories. These efforts reaffirm the role of schools as spaces of biocultural resistance, where LEK and scientific knowledge can enter a productive dialogue and mutually enrich one another.

The inclusion of ethnobotany into formal education, particularly when rooted in Local Ecological Knowledge, holds the power to renew environmental education by cultivating critical socio-environmental awareness among youth in marginalized and ecologically sensitive regions. To nurture these emergent practices, we recommend: the co-creation of teaching materials with traditional communities to honor and valorize local knowledge; the transformation of teacher training through intercultural and place-based approaches; the formation of collaborative networks between schools, universities, and traditional knowledge holders; the use of Didactic Sequences as structured pathways for translating LEK into classroom practice; and the integration of ethnobotany and climate justice as core dimensions of science curricula. These actions are fundamental to shaping a more inclusive, critical, and ecologically grounded science education that empowers future generations to understand and respond to the socio-environmental crises of our time.

Declarations

List of abbreviations: DS - Didactic Sequences; LEK - Local Ecological Knowledge; UFPs - Unconventional Food Plants; PICS - Práticas Integrativas e Complementares em Saúde; SUS - Sistema Único de Saúde.

Ethics approval and consent to participate: All participants were informed of the purpose of the research. They all gave informed consent to share information. The study was approved by the Research Ethics Committee of the Federal University of Bahia (Protocol No. 7.489.905, CAAE: 87066624.3.0000.5531).

Consent for publication: Not applicable.

Availability of data and materials: The data generated and analyzed are included in this article.

Competing interests: We declare that we have no conflict of interest.

Funding: This research was supported by the Bahia Research Support Foundation (FAPESB) and the Brazilian National Council for Scientific and Technological Development (CNPq).

Author contributions: FMG: Idea and conceptualize article writing, methodology, data collection and analysis. MSSLS: Contributed to interviews, the data analysis and reviewed the manuscript. LOLR and LMDV: Supervised the study, contributed to the theoretical framework and reviewed the text.

Acknowledgements

We would like to thank the Bahia Research Support Foundation (FAPESB) and the Brazilian National Council for Scientific and Technological Development (CNPq) for research funding support. We also thank each Biology teacher who contributed to this research and shared their knowledge. We extend special gratitude to the school leaders who facilitated our work in the communities across Brazil.

Literature cited

Albuquerque UP, Hanazaki N. 2009. Five problems in current ethnobotanical research—and some suggestions for strengthening them. Human Ecology 5:1-8. doi: 10.1007/s10745-009-9259-9.

Alexiades MN (ed). 1996. Selected Guidelines for Ethnobotanical Research: A Field Manual. The New York Botanical Garden, Bronx, USA.Bardin L. 2011. Análise de conteúdo. Edições 70, São Paulo, Brazil.

Bascopé M, Salazar D, Arenas A, Morales R, Merino C, Cisternas D, Ampuero P. 2025. Teacher continuous professional development in climate change education: Analyzing teachers' perspectives. The Journal of Environmental Education 56(4):285-306. doi: 10.1080/00958964.2025.2471971.

Berkes F. 2012. Sacred Ecology, 3rd ed. Routledge, New York, USA.

Biswas S. 2023. A review of socio-economic vulnerability: The emergence of its theoretical concepts, models and methodologies. Heliyon 9:e17543. doi: 10.1016/j.heliyon.2023.e17543.

Bonilla-Mejía L, Londoño-Ortega G, Henao MF. 2024. Geographic isolation and learning: Evidence from rural schools in Colombia. Economics of Education Review 99:102522. doi: 10.1016/j.econedurev.2024.102522.

Brazil. 2007. Decreto nº 6.040, de 7 de fevereiro de 2007. Institui a Política Nacional de Desenvolvimento Sustentável dos Povos e Comunidades Tradicionais (PNPCT). Presidência da República, Brasília, Brazil. Available at: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/decreto/d6040.htm.

Brondizio ES, Aumeeruddy-Thomas Y, Bates P, Carino J, Fernández-Llamazares Á, Ferrari MF, Galvin K, Reyes-García V, McElwee P, Molnár Z, Samakov A, Shrestha UB. 2021. Locally based, regionally manifested, and globally relevant: Indigenous and local knowledge, values, and practices for nature. Nature Climate Change 11:1-10. doi: 10.1038/s41558-021-01213-4.

Campani G. 2024. Indigenous education in Brazil - The case of the Baré people in Nova Esperança: Transition to work and sustainability. Social Sciences 13(9):481. doi: 10.3390/socsci13090481.

Conde BE, Ticktin T, Fonseca AS, Macedo AL, Orsi TO, Chedier LM, Rodrigues E, Pimenta DS. 2017. Local ecological knowledge and its relationship with biodiversity conservation among two Quilombola groups living in the Atlantic Rainforest, Brazil. PLoS ONE 12(11):e0187599. doi: 10.1371/journal.pone.0187599.da Silva C, Pereira F, Amorim, JP. 2023. The integration of indigenous knowledge in school: a systematic review. Compare: A Journal of Comparative and International Education. doi: 10.1080/03057925.2023.2184200.

El-Hani CN, Ludwig D. 2025. Intercultural education as dialogue between knowledge systems: elements of a theoretical framework. Science & Education 34:2797-2844. doi: 10.1007/s11191-024-00525-z.

Ennes M, Lawson DF, Stevenson KT, Peterson MN, Jones MG. 2021. It's about time: perceived barriers to in-service teacher climate change professional development. Environmental Education Research 27(5):762-778. doi: 10.1080/13504622.2021.1909708.

Foss BA, Ko JB. 2019. Barriers and opportunities for climate change education: The case of Dallas-Fort Worth in Texas. The Journal of Environmental Education 50(3):145-159. doi: 10.1080/00958964.2019.1604479.

Franco FM, Narayanan MKR. 2021. Resilience and ethnobotany: a narrative review. Economic Botany 75(2):139-153. doi: 10.1007/s12231-021-09524-5.

Gaoue OG, Coe MA, Bond M, Hart G, Seyler BC, McMillen H. 2017. Theories and major hypotheses in ethnobotany. Economic Botany 71:1-19. doi: 10.1007/s12231-017-9389-8.

Hargreaves A. 1994. Changing teachers, changing times: teachers' work and culture in the postmodern age. Teachers College Press, New York, USA.

Ige OA, Jita LC. 2020. Instructional practices of science teachers in rural learning ecologies. Journal of Baltic Science Education 19(5):780-803. doi: 10.33225/jbse/20.19.780.

Iocca L, Fidélis T. 2023. Are the rights and knowledge of indigenous peoples and local communities being attended to by climate framework laws? Climate Policy 24(8):1004-1017. doi: 10.1080/14693062.2023.2262416.

IPCC. 2022. Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. https://www.ipcc.ch/srccl/.

Júnior WS. 2020. Reflections on the theoretical advances in ethnobiology: are we pointing in the wrong direction? Ethnobiology and Conservation 9(20)1-8. doi: 10.15451/ec2020-05-9.20-1-8.

Kungu E. 2025. Ethnobotanical approaches: integrating traditional knowledge into modern healthcare. Newport International Journal of Scientific and Experimental Sciences 6(3):43-50. doi: 10.59298/NIJSES/2025/63.4350.

Ladio AH, Molares S. 2013. Evaluating traditional wild edible plant knowledge among teachers of Patagonia: patterns and prospects. Learning and Individual Differences 27:241-249. doi: 10.1016/j.lindif.2013.04.002.

Leach T, Bradbury O. 2024. Equipping teachers for success in rural communities: Unveiling the key characteristics and attributes of thriving Rural teachers. Education Sciences 14(12):1384. doi: 10.3390/educsci14121384.

Lezcano Acuña RC, Hilgert NI. 2023. Desafíos y oportunidades de la enseñanza de la biología en contextos interculturales: la etnobiología como herramienta para la incorporación de los conocimientos ecológicos tradicionales. Ethnoscientia 8(3):55-74. doi: 10.18542/ethnoscientia.v8i3.14970.

Lima MEA, Fiori APSM. 2023. Educação ambiental para povos e comunidades tradicionais no ensino técnico integrado: como ensinar para quem nos ensina? Revista Brasileira de Educação Ambiental 18(6):502-523. doi: 10.34024/revbea.2023.v18.15073.

Marsandi F, Sutadji E, Kuntadi I, Rizal F, Rahma ABN, Fajri H. 2025. Integrating ethnobotany and indigenous knowledge into higher education curricula: insights from a global biobibliometric analysis. Ethnobotany Research and Applications 30(17): 1-12. doi: 10.32859/era.30.17.1-12.

McCarter J, Gavin M. 2011. Perceptions of the value of traditional ecological knowledge to formal school curricula: Opportunities and challenges from Malekula Island, Vanuatu. Journal of Ethnobiology and Ethnomedicine 7:38. doi: 10.1186/1746-4269-7-38.

McAlvay AC, Armstrong CG, Baker J, Black Elk L, Bosco S, Hanazaki N, Joseph L, Martínez-Cruz TE, Nesbitt M, Palmer MA, Almeida WCP, Anderson J, Asfaw Z, Borokini IT, Cano-Contreras EJ, Hoyte S, Hudson M, Ladio AH, Odonne G, Peter S, Rashford J, Wall J, Wolverton S, Vandebroek I. 2023. Ethnobiology Phase VI: Decolonizing Institutions, Projects, and Scholarship. Journal of Ethnobiology 41:170-191. doi: 10.2993/0278-0771-41.2.170.

Mkhwebane LN. 2024. Life sciences teachers' integration of indigenous knowledge: a vision for making science classrooms more meaningful. EURASIA Journal of Mathematics, Science and Technology Education 20(8):14859. doi: 10.29333/ejmste/14859.

Mota MRL, Lauer-Leite ID, Novais JS. 2023. Intergenerational transmission of traditional ecological knowledge about medicinal plants in a riverine community of the Brazilian Amazon. Polibotánica 56:311-329. doi: 10.18387/polibotanica.56.16.

Oliveira DMS, Miranda ACG. 2024. Etnobotânica e o Ensino de Ciências: valorização das comunidades tradicionais em tempos de crise. Práticas Educativas, Memórias e Oralidades 6:e13428. doi: 10.47149/pemo.v6.e13428.

Parmesan C, Hanley ME. 2015. Plants and climate change: complexities and surprises. Annals of Botany 116(6):849-864. doi: 10.1093/aob/mcv169.

R Core Team. 2024. R: A language and environment for statistical computing. Version 4.3.3. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Reyes-García V, Martí N, McDade T, Tanner S, Vadez V. 2007. Concepts and methods in studies measuring individual ethnobotanical knowledge. Journal of Ethnobiology 27(2):182-203. doi: 10.2993/0278-0771(2007)27[182:CAMISM]2.0.CO;2.

Reyes-García V, Kightley E, Ruiz-Mallén I, Fuentes-Peláez N, Demps K, Huanca T, Martínez-Rodríguez MR. 2010. Schooling and local ecological knowledge: Do they complement or substitute each other? International Journal of Educational Development 30(3):305-313. doi: 10.1016/j.ijedudev.2009.11.007.

Reyes-García V, Fernández-Llamazares Á, McElwee P, Molnár Z, Öllerer K, Wilson SJ, Brondizio ES. 2019. The contributions of Indigenous Peoples and local communities to ecological restoration. Restoration Ecology 27(1):3-8. doi: 10.1111/rec.12894.

Rico Lenta C, Ladio AH, Rovere AE. 2023. Niñez y conocimientos ecológicos locales de los bosques andino-patagónicos de Argentina. Recomendaciones para el trabajo etnobiológico en el aula. Ethnoscientia 8(3). doi: 10.18542/ethnoscientia.v8i3.14959.

Robles-Piñeros J, Ludwig D, Baptista GCS, Molina-Andrade A. 2020. Intercultural science education as a trading zone between traditional and academic knowledge. Studies in History and Philosophy of Science Part C 84:101337. doi: 10.1016/j.shpsc.2020.101337.

Rocha JA, Boscolo O, Fernandes LR. 2015. Etnobotânica: um instrumento para valorização e identificação de potenciais de proteção do conhecimento tradicional. Revista Interações 16(1):67-74. doi: 10.1590/151870122015105.

Santos TI, Cavalcanti DR. 2022. The contributions of didactic sequences in the teaching and learning process in science for the study of ecological relationships. Experiências em Ensino de Ciências 17:170-180.

Silva JJ, Hora PHA, Santos MS. 2025. Use of didactic sequence in science teaching: Application of active methodologies as a learning simplifier with emphasis on chemistry teaching. Revista Signare Scientia 8(1):1-21. doi: 10.36661/2595-4520.2025v8n1.14580.

Souza EB, Almeida CMS, Santos MAF. 2022. Investigative didactics sequences in science teaching: a teaching training experience during remote teaching. Revista Macambira 6(1):e061005. doi: 10.35642/rm.v6i1.699.

Souza EO, Machado VM. 2018. Sequência didática no processo de formação inicial de professores de Ciências Biológicas. Revista De Ensino De Biologia Da SBEnBio 11(2):77-84. doi: 10.46667/renbio.v11i2.176.

Tesser CD, Sousa IMC, Nascimento MC. 2023. Traditional and complementary medicine in primary health care in Brazil. Saúde em Debate 42:174-188. doi: 10.1590/0103-11042018S112.

UNESCO. 2021. Reimagining our futures together: a new social contract for education. UNESCO, Paris, France. https://unesdoc.unesco.org/ark:/48223/pf0000379707.

Van Luijk N, Soldati GT, Fonseca-Kruel VS. 2021. The role of schools as an opportunity for transmission of local knowledge about useful Restinga plants: experiences in southeastern Brazil. Journal of Ethnobiology and Ethnomedicine 17:34. doi: 10.1186/s13002-021-00461-0.

Vorpagel FS, Cousin CS. 2024. Environmental education in the National Common Curricular Base: advances and setbacks in Basic Education in contexts of traditional peoples and communities. Revista Exitus 14:e0240242.

Wanjohi BK, Njenga EW, Sudoi V, Kipkore WK, Moore HL, Davies MI. 2020. Ethnobotanical study of traditional knowledge, sustainable uses and management of indigenous non-medicinal plants among the Marakwet Community (Embobut Basin), Elgeyo Marakwet County (Kenya). Ethnobotany Research and Applications 20(1):1-16. doi: 10.32859/era.20.1.1-16.

Yemini M, Engel L, Ben Simon A. 2025. Place-based education - a systematic review of literature. Educational Review 77(2):640-660. doi: 10.1080/00131911.2023.2177260.

Zabala A. 1998. A Prática Educativa: Como Ensinar. Editora ARTMED, Porto Alegre, Brazil.