

# Intercultural science education as a trading zone between traditional and academic knowledge

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## ABSTRACT

Intercultural science education requires negotiations between knowledge systems and of tensions between them. Building on ethnographic fieldwork and educational interventions in two farming communities in the Northeast of Brazil, we explore the potential of science education to mediate between traditional and academic knowledge. While traditional knowledge shapes agricultural practices and interactions with the environment in the villages of Coração de Maria and Retiro, academic knowledge is emphasized in biology education. On the basis of philosophical debates about “partial overlaps” between epistemologies, ontologies and value systems, we analyze relations between traditional and academic ecological knowledge in these communities and argue that they can inform reflective practices in intercultural dialogue. By investigating biology education as a “trading zone” between knowledge systems, we analyze how partial overlaps become negotiated in educational practices in rural Brazil and provide the basis for educational interventions that foster intercultural dialogue.

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## 1. Introduction

Knowledge about the biological world is produced by heterogeneous epistemic communities in and beyond academia. Many challenges in the life sciences require recognition of this knowledge diversity in domains such as agriculture, biodiversity conservation, and public health. Ethnobiology has emerged as an integrative field that studies Traditional Ecological Knowledge (TEK) and the expertise of heterogeneous actors beyond academia (Byskov, 2017; Hansson, 2019; Turnhout et al., 2019). While the increased recognition of TEK creates opportunities for better participation and representation of local communities through collaborative practices, its interaction with Academic Ecological Knowledge (AEK) also creates complex methodological challenges.

As Ludwig and El-Hani (2020) have pointed out, attempts to integrate TEK and AEK often fail in the light of different epistemologies, ontologies, and values of actors. Furthermore, these tensions are

intertwined with political questions as academic researchers and local communities tend to be in very different positions of power in enacting their epistemologies, ontologies, and values in collaborative practices. Political shortcomings of integration projects have also become widely reflected in the anthropological literature (Kimmerer, 2011; Nadasdy, 2003), which emphasizes that integration projects can lead to assimilation when TEK is treated as additional data and only considered insofar as it is validated by or useful for AEK. Anthropologists therefore often emphasize differences between TEK and AEK along the lines of “radical alterity”, “incommensurability”, or “different worlds” that are inhabited by Western researchers and Indigenous communities (Henare et al., 2007; Viveiros de Castro, 2014).

While the anthropological literature emphasizes risks of overly optimistic integration projects, pessimistic claims of incommensurability between AEK and TEK run the risk of negating the possibility of intercultural dialogue and the development of culturally sensitive practices in science education. Extending Galison’s (1997) framework of “trading zones” from scientific collaboration to transdisciplinary negotiation, we suggest to move beyond simple narratives of integration or incommensurability by investigating the dynamics of negotiation processes that “can hammer out a local coordination, despite vast global

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differences [and] establish; contact languages, systems of discourse" (Galison, 1997, p. 783).

This article focuses on intercultural science education as an important trading zone in two farming communities, Coração de Maria and Retiro, in the state of Bahia in Brazil. *Section 2* develops a theoretical framework that combines ethnobiological models of "partial overlaps" of knowledge systems with the notion of "trading zones" in order to analyze dynamics in intercultural science education. *Section 3* introduces the empirical case study of the villages Coração de Maria and Retiro as well as our methodology for engaging with local agricultural and educational activities. *Section 4* analyses partial overlaps between AEK and TEK in Coração de Maria and Retiro through three case studies of agricultural and taxonomic practices. *Section 5* explores these partial overlaps in the context of local biology education and *Section 6* develops the idea of intercultural science education as a trading zone between TEK and AEK.

## 2. A framework for intercultural dialogue

Science education in the villages of Coração de Maria and Retiro constitutes a complex meeting ground for epistemic traditions. In many contexts of the "Global South", the introduction of formal schooling raises concerns about the simultaneous introduction of hierarchies between knowledge systems that present academic knowledge as authoritative while marginalizing local knowledge and practices of knowledge transmission (Reyes García et al., 2010; Sumida Huaman & Valdiviezo, 2014). As Kimmerer (2002, p. 432) puts it: "in our biology curricula, we are perhaps unknowingly ignoring an entire body of knowledge that has potential significance to contemporary science and policy: traditional ecological knowledge (TEK)." However, the increased academic recognition of TEK has also led to a wide range of proposals for integrating local expertise about environments and biota into educational practices (Brosi et al., 2007; Kim et al., 2017; Kimmerer, 2012; Longboat et al., 2013).

Growing academic concerns with TEK complement intercultural approaches in the field of science education that emphasize the importance of dialogue between heterogeneous knowledge systems and articulate the ambition of expanding students' understanding of science by providing them with opportunities to reflect on different epistemic traditions and their contextualized applications (Robles-Piñeros, Barboza & Baptista, 2017). Current research in intercultural science education is seeking to incorporate students' prior knowledge by proposing methodologies and strategies that are sensitive to the context and cultural diversity of these communities, see Cobern and Loving (2001); El-Hani and Mortimer (2007); El-Hani & Bandeira (2009); Baptista and El Hani (2009); Molina Andrade and Mojica (2013); Molina Andrade (2014; 2017); Valderrama-Perez et al. (2017); Baptista (2009; 2018) and, Robles-Piñeros (2017), Robles-Piñeros & Baptista (2018).

Intercultural science education commonly departs from a characterization of science as culture in the sense of Geertz' (1973) definition of culture as "an orderly system of meanings and symbols, in whose social terms the interaction takes place" (Aikenhead, 1996; Cobern & Loving, 2001; Elkana, 1983). Recognizing science as culture turns classrooms into intercultural meeting grounds between cultures of science that are often represented by the teacher and the curriculum, and local cultures that are represented by students through contents, commitments, knowledge, and values.

Especially in the Global South, intercultural science education aims to relate these cultures (Molina Andrade, 2014) by (a) addressing tensions and exclusions that require challenges of epistemic hierarchies in the curriculum (Snively & Corsiglia, 2001; Cobern, 1996; Quintrique & McGinity, 2009) and (b) creating space for debate of cultural differences and dialogues between varied and different knowledge systems (Baptista & El Hani, 2009; Cobern & Loving, 2001; El-Hani & Mortimer, 2007; Molina Andrade & Mojica, 2013; Valderrama et al., 2015). TEK plays an important role in this case for intercultural education as its

erosion does not only lead to a loss of biocultural heritage but also of practices that are crucial for local livelihoods. The integration of TEK into educational programs has therefore also become a concern in the development of teacher trainings that aim to increase sensitivity to cultural diversity among science teachers and helps them to value cultural differences (Baptista, 2015; Bicker et al., 2004; Molina-Andrade et al., 2017).

While intercultural science education creates opportunities for the recognition of local knowledge systems, it also raises complex philosophical questions about the relationship between them. Optimistic narratives of intercultural understanding often remain insufficiently reflective about methodological and political challenges of bringing together TEK and AEK (Ludwig & El-Hani, 2020; Nadasdy, 2003; Nigh, 2001). Incorporating bits of TEK into formal schooling may come with good intentions while reproducing hierarchies in which TEK needs to prove its usefulness against standards that are set by Western scientific and educational traditions. At the same time, there is also a risk of overly pessimistic narratives of incommensurability that cast doubt on the very possibility of intercultural dialogue and of developing culturally sensitive practices in science education.

Our study addresses these methodological challenges by situating an ethnobiological and educational research project from Brazil in two theoretical debates. First, we adopt recent models from ethnobiological theory (Ludwig, 2016; Ludwig & El-Hani, 2020) that emphasize "partial overlaps" between TEK and AEK. Ludwig and El-Hani locate overlaps between TEK and AEK in (a) epistemological dimensions of generating and validating knowledge, (b) ontological dimensions of reasoning about the structure of the natural world, and (c) normative assumptions about interactions with environments and biota. First, we adopt the framework of partial overlaps as a descriptive model of the relation between knowledge systems that can lead to a more nuanced analysis of points of convergence as well as divergence beyond generic claims of commensurability or incommensurability. Second, we treat "partial overlaps" not only as a descriptive model but also as a prescriptive method for actively seeking out points of agreement that can provide common ground in intercultural dialogue as well as disagreements that need to be fairly negotiated in order to overcome subordination of TEK to AEK.

In a second step, we take this model and method of partial overlaps into the educational domain by showing how it can contribute to critically self-reflective practices of intercultural science education. In developing this account, we start with the notion of "trading zones" that has been introduced by Galison (1997) into the history and philosophy of science. Galison's account aims to understand the success of collaborative practices in microphysics despite heterogeneous "forms of work, modes of demonstration, ontological commitments [that] all differ among the many traditions that compose physics at any given time in the twentieth century" (1997, 789). The notion of trading zones adds a more dynamic component to the model of partial overlaps by showing how the interaction of knowledge systems and material practices can lead to the emergence of novel meanings and forms of collaboration.

Interpreting intercultural classrooms as trading zones between partially overlapping knowledge systems provides resources for critically reflective engagement with science education beyond overly optimistic accounts of harmonious knowledge integration and overly pessimistic narratives that cast doubt on the very possibility of successful collaboration. Furthermore, the context of science education in the Global South also adds further dimensions to current debates about trading zones. First, it expands the focus from interdisciplinary interaction between scientific subcultures in an academic field such as microphysics to transdisciplinary interactions between academics (e.g. agricultural scientists, conservation biologists) and non-academic (e.g. farmers and their children) actors (Gorman, 2018; Rosbach, 2012). Second, transdisciplinary settings in rural Brazil sharpen the focus on the political dynamics of trading zones that have also become increasingly reflected in social studies of science (Galison, 2010; Murphey et al., 2016).

### 3. Study context and methods

This study was carried out with two farming communities from the municipality of Coração de Maria in the state of Bahia, Brazil - the first located near the urban area of Coração de Maria and the second located 19 km apart in the district of Retiro. In the middle of the 20th century, Coração de Maria has been known as the “pineapple city of Bahia” as the municipality was famed for producing the largest quantity and highest quality pineapples in the state. While this agricultural fame contributed to economic development, the economic conditions of the municipality have deteriorated and its residents are now struggling with peasant marginalization and a lack of investment in the rural areas by the government. This development is not entirely new and Baptista (2007) already related it to a growing tendency of cultural erosion that resulted in an undervaluation of local cultural traditions including TEK by young people in Coração de Maria (Baptista, 2007; Baptista & El Hani, 2009; Robles-Piñeros, 2017).

The people from Coração de Maria and Retiro have a complex relationship with their environment that is shaped by tensions between conflicting biocultural realities. On the one hand, the communities have rich traditions of integrating farming techniques, biodiversity, and cultural meaning into a distinctly local biocultural system (Boege, 2008; Patrick-Encina & Bastida-Muñoz, 2010; Toledo & Barrera-Bassols, 2015). On the other hand, the local economy is increasingly dominated by conventional agriculture that is entangled with the development of the agri-food industry and urbanization of the area. In this complex context, schools play an important role in the process of mediation between different forms of knowledge and practices. Students commonly experience tensions between knowledge that is transmitted through their families and academic knowledge that is presented in the classroom. These tensions are often deeply political in the sense that they reflect discrimination and rejection of TEK by part of the teachers and the school system more generally.

Our research employed a transdisciplinary research methodology (Fig. 1) that combined (1) ethnographic research on TEK of the local communities, (2) philosophy of science as a tool for reflecting on underlying epistemological and ontological issues, and (3) participatory action research that involved local educational interventions. Therefore, we triangulate three domains of inquiry that are typically left apart: (1) empirical research, (2) philosophical reflection, and (3) educational intervention. Our study has been based on the assumption that such triangulation can lead to an innovative transdisciplinary methodology that comes with epistemic as well as applied benefits. First, we aim to show how philosophical reasoning about knowledge diversity can

benefit from careful empirical research while ethnographic engagement with TEK can simultaneously benefit from intellectual resources that have been developed in academic philosophy. Second, we assume that such a partly empirical and partly philosophical research methodology can contribute to the design of educational interventions that are critically reflective about the (empirical, epistemological, ethical, ontological, political) complexity of navigating knowledge diversity.

We initiated our study in two local public schools of Coração de Maria and Retiro by asking students whether they are interested in participating in this research. Afterwards, we acquired informed consent from their families, formed student groups, and selected more specific sites for field visits. The study was designed as a participatory research project in the sense that decisions and planning were developed in a group that involved the students and in common agreement with the teachers of each school. Through this participatory methodology, we proceeded to schedule visits in open time slots during the school day and the work was approved and protected by the ethics committee of the State University of Feira de Santana, under resolution CONSEPE (*Conselho Superior de Ensino Pesquisa e Extensão*) n. 097–2018.

Our qualitative research methods (Creswell, 2010) included participant observation and knowledge sharing (Kawulich, 2005) during field visits to the crops and work sites of the communities. Due to the participatory nature of the research project, informal interviews and conversations with farmers (students’ parents) in the region were always mediated by their children and with the active participation of school science teachers. Following field visits to families of students and analysis of information, we developed an educational intervention aimed to teach ecology through intercultural dialogue.

### 4. Partial overlaps between agricultural knowledge systems

This section explores “partial overlaps” (Ludwig, 2016; Ludwig & El-Hani, 2020) between knowledge systems in Coração de Maria and Retiro through three case studies that address interrelated aspects of how to maintain and care for crops, recognize and classify insects of agricultural importance, understand insect-plant relationships, and detect patterns of development and inhabitation of plants by caterpillars. We show that farmers in Coração de Maria and Retiro (who are also parents of the students in our educational intervention) possess a wealth of agricultural, biological, and ecological knowledge that grounds sustainable engagement with environments while contributing to livelihoods, food security, and biocultural heritage of the communities.

Some of this TEK is shown to complement academic knowledge by converging with agroecological practices and academic classifications of local taxa. In other cases, we identify tensions between knowledge systems and practices. On the knowledge side, we find that ethno-entomological classifications of insects often reflect local patterns of agricultural significance but diverge from classificatory systems in biological taxonomy. Furthermore, traditional agricultural practices often create tensions with productivist paradigms of agricultural modernization that assimilate local communities into an industrialized agri-food economy. The case studies of this section therefore lead to a complex picture beyond simple narratives of seamless knowledge integration or a clash of incommensurable worlds.

#### Case 1: Use of wild vegetation for fostering crops

Global agricultural development is closely intertwined with a paradigm of agricultural modernization that exports Western technologies into the “rest of the world” with the goal of increasing agricultural productivity. As critical discussions of the “Green Revolution” (e.g. Kilby, 2019; Lansing, 2009; Scott 1999) have argued in detail, the export of technologies such as fertilizers, machines, pesticides, and seed varieties has often been accompanied by disregard and marginalization of traditional agricultural knowledge and practices. In many cases, the consequences of this unidirectional technological export have been

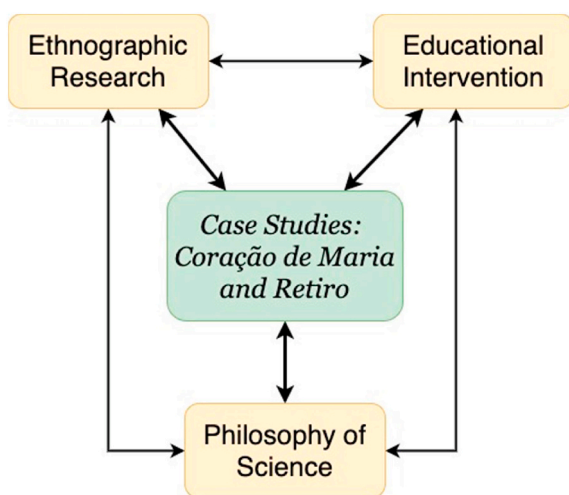


Fig. 1. Model of transdisciplinary research design in which three approaches are applied to the case study but also mutually influence each other.



catastrophic for local communities by erasing sustainable relations with environments. Whether it is soil erosion through agricultural intensification, loss of food security through land grabbing and monoculture, pest outbreaks through reduced biodiversity, or destruction of local economies through global market integration - a simple export of modern agricultural technologies is permeated with (intended or unintended) consequences that burden the most vulnerable stakeholders in agri-food economies.

The destruction of biocultural heritage and local livelihoods through unidirectional technological export of “Green Revolution” modernization has become widely recognized as a core challenge in the development domain (Behnassi et al., 2014; Ceccon, 2008; Conway & Barbier, 2013) and contributed to an increased recognition of TEK in alternative approaches such as “agroecology” (Holt-Giménez & Altieri, 2013) and “integrated pest management” (Fonseca et al., 2013) or “responsible innovation” (Ludwig & Macnaghten, 2019). Under such alternative perspectives, many local practices in Coração de Maria and Retiro can provide the basis for innovative agricultural practices. One of them is the use of “mato” (bush and wild plants) in the cultivation process of Manioc (*Manihot esculenta*) and corn (*Zea mays*) (Fig. 2). Sowing their crops together with this type of “stubble” of wild plants makes crops grow better and the people argue that it helps to “the soil does not get tired”. As one of the interviewed farmers put it:

“... We do it (the use of grass, and wild plants), to prevent pests that come and attack our crops, then, for example, the manioc keeps “bichada” [roughly “bugged”, i.e. a large quantity of bugs], my parents did it and my grandfather too [...] Also my grandfather told me that if you do not do it, it will tire the soil ...” (Seu C. (local farmer) (2019).

Participant observation and interviews with farmers revealed that this practice is far from trivial but has a variety of uses that make “mato” an important dimension of TEK in Coração de Maria and Retiro. The use of bush and wild plants in agricultural practices has acquired a meaning beyond purely pragmatic perspectives for the farmers of the region.



Fig. 2. Manioc crop (*Manihot esculenta*) surrounded by grass and “wild plants”. According to the farmers, this practice helps the soil and protects the manioc plants. Photography from the researcher (2019).

Instead, mato has come to represent the wider significance of organic farming as the biocultural heritage of the community that is increasingly marginalized through the influence of conventional agriculture and the erosion of TEK. Through our work with the farmers, we also identified several reasons for using mato in their crops. First, the use of wild plants and bush provides protection of crops from pests and predators. Second, mato helps to avoid soil erosion and to replace nutrients in the soil. Third, the wild plants also support the growth of new plants and protect the sprouts from dehydration and direct exposure to the sun. As Seu J. says:

“... We do this (cultivating Manioc or Corn with wild plants) because it is very hot here, and when the sun hits here in Bahia our crops are also affected [...] the sprouts can dry out and die, so we put the bush to protect those new plants” Seu J. (local farmer).

The case of mato illustrates the potential of productive synergies between TEK and AEK. Agricultural scientists and development practitioners have come to recognize the need for sustainable agricultural practices that reduce reliance on chemical inputs (e.g. pesticides and fertilizers) and the importance of developing alternative strategies of biocontrol. Mato complements these approaches as it provides a strategy for biocontrol and soil fertilization that does not require chemical inputs and simultaneously increases biodiversity in the environment. The recognition of TEK in Coração de Maria and Retiro therefore provides innovative resources for agroecological practices that are also increasingly embraced by academically trained agricultural researchers and development practitioners. Furthermore, TEK around mato also converges with AEK in a more narrow sense as research in plant ecology (Garibaldi, 2016; Lacey, 2014, 2015; Wezel et al., 2015) agrees on the importance of accompanying species for crops that increase pollinators through diversity as a mutual beneficial ecological system (Aizen et al., 2019; Potts, Imperatriz-Fonseca & Ngo, 2016) that diminishes the impact of predation by insects, protects from outbreaks of desiccation and insolation, and helps to replace nutrients in the soil.

#### Case 2: Agricultural Triplets (Maize, Manioc, and others)

Conventional agriculture in Coração de Maria and Retiro is based on a production system dependent on the high use of synthetic inputs, where monoculture is justified as an essential tool for achieving greater efficiency in the production process. While this production system has become dominant across Brazil (Macnaghten & Carro-Ripalda, 2015), it has also shown serious problems of sustainability and has caused the deterioration of natural resources in the region. In contrast, agroecology is a development strategy that is based on improving the soil, encouraging the use of local inputs, and implementing fairer value chains in the agri-food domain (Betancur, Giron & Betancur, 2018). One of the most important practices among the farmers in Retiro’s municipality is mixed cropping with three different types of plant species (Fig. 3). This so-called “triplet” is usually composed of maize (*Zea mays*), manioc (*Manihot esculenta*) and beans (*Phaseolus vulgaris*). However, the beans can also be substituted with other species such as eggplants (*Solanum melongena*). Farmers point out that the use of these triplets comes with crucial benefits compared to monoculture:

“In this way we can put together these three, and then we always have something to get, to eat and to sell [...] is because in this way of culture I put, for example, the maize and eggplant together, and in-between them I put the manioc, then they grow-up together and share the space and the soil.” Dona E. (local farmer)

Practices of mixed cropping are not exclusive to farmers in Bahia. Instead, variations of this triplet are found in traditional communities around the world including the “Milpa” in Maya communities in Mexico. Milpa is a famous Indigenous practice of mixed cropping that has been widely recognized in the academic literature including DAlessandro and



Fig. 3. A triplet of crops, in this case, mixed cropping of maize (*Zea mays*), manioc (*Manihot esculenta*) and cucurbit (*Abobra sp.*). Photography from research (2019).

Gonzalez (2017); Cahuich-Campos et al. (2014). Other countries that have developed similar practices within their traditional communities are Peru and Bolivia. Many of these mixed cropping practices do not only contribute to food security and soil sustainability but also reflect the wider cultural heritage of communities. For T'zeltal Maya, for example, Milpa expresses an intimate relationship between the cosmogony of community and the structure as well as the use of crops. In this sense, Milpa is widely used as a representation of nature and space for mythical understanding (DAlessandro & Gonzalez, 2017).

Traditional methods of mixed cropping such as the triplets of Coração de Maria and Retiro converge with concerns of many academic researchers in developing integrative agroecological practices that improve productivity and health of both crops and soils (Fess et al., 2011; Wachter Rodarte, 2018; Widmer & Krebs, 1997). In this sense, there are clear opportunities for knowledge integration that focus on overlaps between farming practices of the communities and agroecological strategies that aim to contribute to food security and sustainability. However, there are also continuous tensions between traditional practices of mixed cropping and conventional monoculture farming. In most cases, farmers of Coração de Maria and Retiro also employ conventional farming practices. This often results in socio-environmental tensions between the two production systems, one focused on maintaining sustainable farming and the other focused on intensification and increased production, sometimes putting in danger the food sovereignty and livelihoods of the people. This tension is also reflected in a process of cultural erosion among new generations who undervalue their own cultural knowledge and are looking for opportunities to leave the villages. Furthermore, it is reflected in socioeconomic deterioration in which some villagers do not have the possibility to maintain their traditional farming practices and are forced to adopt a production system to which they are not accustomed and that makes them dependent on supplies they cannot afford to maintain their crops.

#### Case 3: Recognition and Classification of Insects

Our third case addresses classificatory practices and focuses on ethnoentomological accounts of insects of agricultural importance. Many seminal studies in ethnotaxonomy (e.g. Berlin, 1992; Hunn, 1977) emphasize similarities between classificatory systems of TEK and AEK by arguing that both recognize the same natural kinds and biological structures. Local farmers and academic researchers may have very different pragmatic interests but still converge in their biological ontologies as they all recognize the same “discontinuities in nature” (cf. Ludwig, 2018; Ludwig & Weiskopf, 2019).

There are many examples of taxonomic convergence between TEK and AEK in Coração de Maria and Retiro. Our study focused on insects that are of agricultural importance and that farmers are intimately familiar with. We found that farmers often employ a “utilitarian perspective” (Hunn, 1982) in classification of insects by focusing on features that are important for agricultural practices such as the type of plant they attack and the morphological features that allow their identification. Despite this utilitarian focus on criteria that are shaped by non-epistemic (Ereshefsky & Reydon, n.d.; Ludwig, 2016) agricultural concerns, local ethnotaxa often converge on taxa that are recognized by academic researchers. One striking example in the farmer community of the Retiro is the lesser cornstalk borer (*Elasmopalpus lignosellus*) that is locally named “grey corn caterpillar” (*largata cinza do milho*) and considered to be exclusive to maize. Another widely recognized species is the fall armyworm (*Spodoptera frugiperda*) which has a great impact in the development of sprouts (Moreira & Aragão, 2009) and is locally called “green corn caterpillar” (*Largata verde do milho*).

Farmers did not only identify these taxa but also important aspects of the ecology of these species through regular interaction and observation of these organisms. We therefore not only found overlap in the classificatory systems of TEK and AEK (i.e. recognition of the same taxa) but also potential for epistemically productive knowledge integration. One example is the analysis of the gregarious behavior of the larvae of *Automeris sp.* According to the academic literature, individuals leave their gregarious behavior before the metamorphosis to begin their pupae formation process (Comoglio & Racheli, 2016; Drechsel, 2014; Specht et al., 2010). However, the local observations of farmers suggest that larvae of *Automeris sp.* sometimes exhibit gregarious behavior until the process of metamorphosis. The case of gregarious behavior in *Automeris sp.* therefore illustrates how TEK can complement and expand AEK about insect species and their local behavior.

Despite these cases of convergence and potentials for knowledge integration, there are also substantial differences between classificatory practices of TEK and AEK. When talking about the giant silkworm moth (*Diphris moderata* and *Automeris ilustris*), for example, the farmers in Coração de Maria and Retiro use the name “fire-caterpillar” (*largata de fogo*) but treat the caterpillar as a kind that is distinct from the adult moth. This is a case of taxonomic lumping and splitting (Berlin, 1992) in ethnobiological classification. On the one hand, the farmers are lumpers where academic researchers are splitters: For example, the farmers have created a broad category (*largata de fogo*) to refer to organisms that constitute four different species of moth according to academic taxonomy. On the other hand, the farmers are also splitters where academic researchers are lumpers: For example, they treat the caterpillars and the adult moths as distinct categories of animals. As a result, the ethnobiological classifications of the farmers and the biological taxonomies of academic researchers often do not converge and use different categories of insects (Fig. 4).

While divergence in terms of taxonomic lumping and splitting is well-documented in the ethnobiological literature (Berlin, 1992), our research also revealed more surprising and radical forms of taxonomic difference. One striking case is the local classification of organisms in the Pseudococcidae (Coccoidea) family (Fig. 5) as fungi, while academic taxonomies treat Coccoidea as insects of the order Hemiptera (Gullan & Cook, 2007; Kondo et al., 2008). As one farmer explained: “let me see, there is a fungus, it is very small, it almost does not seem to see, but when it arrives it attacks the plant and the plant looks bad and is very difficult to



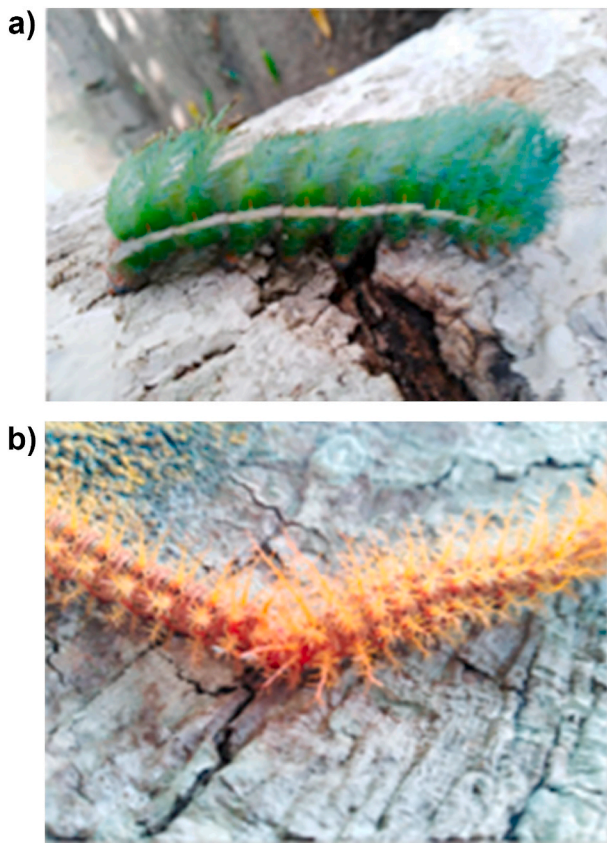


Fig. 4. Two representatives of Saturniid moths (fire-caterpillars): A. *Automeris illustris*; B. *Dirphia moderata*. Photography from research (2019).



Fig. 5. Representatives of the genus *Chrysomphalus* sp. While academic taxonomies classify these organisms as insects of the family Pseudococcidae, local farmers classify them as fungi, giving an example of divergence between biological ontologies. Photography with permission from Almeida (2016).

remove” (Senhora N).

Ethnotaxonomic studies (Costa-Neto, 2002; Price & Bjørnsen Gurung, 2006) show that local classifications of insects often include phylogenetically heterogeneous organisms (e.g. spiders, snakes, myriapods) that share morphological characteristics such as patterns of corporality such as a head, thorax, and extremities. As Coccoidea do not confirm to this morphological pattern, they are not grouped together with other insects or animals, due to the female in this taxonomic group in their imago stage are sessile (Kondo, Gullan and Williams, 2007). Furthermore, these differences in taxonomic practices do not only relate to morphological features but also ecological roles of organisms such as their agricultural significance as an organism that attacks the manioc plants. Rural communities are experts about these species and their

morphological and ecological properties (Bentley, 1989; Bentley et al., 1994) but there also often remains confusion about different stages in the life cycle of certain insect pests (Bentley & Thiele, 1999). To sum up, farmers have a variety of reasons for not treating Coccoidea as insects that include behavioral (the organism is not moving), morphological (the organism does not have an insect-like body) and ecological/agricultural aspects (the organism has similar roles as other fungi). Rather than thinking of diverging classifications as simply wrong, it therefore seems more plausible to situate them in debates about ontological pluralism. As many philosophers of science (Brigandt, 2011; Chakravarty, 2017; Ludwig, 2016b; Winther & Kaplan, 2013) have argued, heterogeneous epistemic and non-epistemic concerns of researchers can lead to equally heterogeneous ontologies in scientific practice. Given the ontological plurality that is already found within scientific practice, it is far from surprising that biological ontologies in Coração de Maria and Retiro are often shaped by local concerns and do not converge on the distinctions of academic researchers (Ludwig, 2018).

## 5. Negotiating knowledge diversity in an intercultural classroom

Our ethnographic study outlines a complex picture of the relation between TEK and AEK in Coração de Maria and Retiro (Fig. 6). On the one hand, we described several points of convergence that suggest opportunities for knowledge integration. First, the examples of “mato” and “triplet crops” illustrate that TEK has innovative answers to sustainability challenges such as the need for a reduction of synthetic inputs and maintenance of food security. Insofar as challenges of more sustainable farming practices are also increasingly recognized in AEK, there are clear opportunities for integrative practices in agroecology. Second, the case study of insect classification identified cases of ontological convergence in which farmers and researchers recognize the same species. As farmers often have localized knowledge about these species (e.g. our case of TEK of gregarious behavior of *Automeris* sp.), their knowledge can productively complement the knowledge that is produced by academic researchers.

On the other hand, our study also identified cases of divergence and tension. First, local practices of “mato” and “triplet crops” may complement sustainable agroecology but are at odds with many practices of conventional agriculture that are economically incentivized and increasingly dominant in Coração de Maria and Retiro. Second, we found that local classificatory practices diverge in important aspects from biological taxonomies as illustrated by cases of “lumping together” of different biological species in ethnotaxa or the treatment of certain insects as fungi. Rather than treating these features as flaws of TEK, we

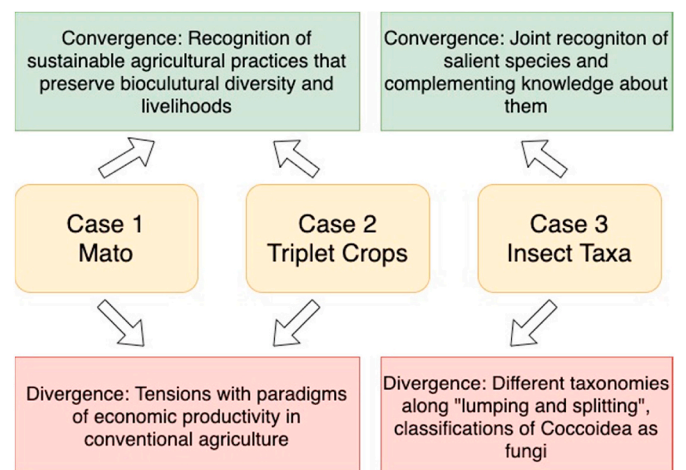


Fig. 6. Summary of both convergences and divergences between TEK and AEK in our three case studies.

argued that these classifications are important for local agricultural practices in the sense that they relate to the ecological roles of organisms and morphological features that are used for their identification in farming practices.

Recall that our documentation of TEK in Coração de Maria and Retiro was based on work with farmers who are simultaneously parents or grandparents of students in local schools. We were also always accompanied by the students when conducting interviews and field visits with their farming families. For the students, TEK practices and classifications from the previous sections are therefore not abstract bodies of knowledge but intimately connected to their daily life and to informal practices of knowledge transmission in the family context. From the perspective of intercultural science education, this constellation raises complex questions about potential synergies between formal schooling and informal transmission of TEK as well as strategies of navigating tensions between them.

With the objective of developing an ecology teaching process based on intercultural dialogue, we set out to design an educational intervention aimed at addressing academic content in AEK through dialogue with TEK on local crops, insects, and practices. Three core foci were defined in the design process: (1) *the experiential knowledge of the teachers*, (2) *the traditional knowledge of the community* and (3) *the possibilities of dialogue between TEK and AEK in ecology teaching*.

Under this perspective, we designed an educational intervention and teaching sequence that understands science as a cultural activity that can identify points of dialogue with other cultural practices during teaching (Robles-Piñeros et al., 2017). The planning process of this educational activity was facilitated through a close relationship between the researcher and the teachers that involved discussion of pedagogical approaches to contextualized ecology teaching and its embedding in concrete cases from daily farming practices. The teaching activity that took place in the two schools, and aimed to address core concepts from ecology such as the notion of ecological relationships (interactions between organisms), energy flows into the ecosystems, food chains, and trophic networks. This selection of concepts was made together with the science teachers and taking into account the curricular guidelines.

Through the overall motto “*bringing ethnoecology to the classroom*”, this intervention led to a dialogue that addressed ecological learning contents through daily situations of the students. As a first exercise, the concept of ecological relations was introduced through insects of agricultural importance that students and farmers recognized from daily experience. Through the use of caterpillars as a teaching model, an approach to concepts of predation, mutualism, and parasitism was developed. This exercise focused on developing an understanding of more abstract concepts of ecological relations through concrete instantiations of these relations in the immediate environment of student farmers. For example, by training the ability to recognize organisms and to relate them to the cycle of matter and the flow of energy (biogeochemical cycles), ecological relationships became understood through the importance of ecosystem dynamics in the specific habitat that students live in (Magntorn & Hellden, 2005).

A second pedagogical exercise with teachers and students was developed through the participatory method of contextual cognition tables (Baptista, 2018). This method seeks to analyze relations between knowledge systems in order to find points of convergence and divergence. Through the use of three columns, contextual cognition tables allow to establish links between students’ cultural knowledge, contents of ecology’s teaching, and scientific content from the scientific literature. Such relations can significantly contribute to dialogues in science classrooms. The exercise turned out to be mutually enriching: for the students because they were able to recognize the importance of their local knowledge and its cultural value and for the teachers as it broadened their pedagogical tools in culturally sensitive science education that locates spaces for dialogue.

During this activity, it also became possible to identify tensions in student reasoning about knowledge systems, specifically when referring

to validity. In addressing these tensions, students reflected on the appropriateness of knowledge systems, developing a critical attitude towards the validity of knowledge and reflexivity about the plurality of ways of creating knowledge about ecological systems. Rather than treating classifications of Coccoidea as fungi as simply wrong, for example, it became possible to explore the use of this classification for local practices while also acknowledging biological reasoning that grounds taxonomies in phylogenetic relationships. Rather than treating “mato” an outdated practice, it became possible to recognize it as a sustainable practice of care for plants and soils.

Tensions and divergences between knowledge systems must be taken into account in the teaching processes with communities. As Kim et al. (2017) point out, it is not enough to include TEK within a science curriculum without a clear methodology for navigating its relation to AEK in the classroom. Indeed, Kim et al. argue that TEK can be used while avoiding the difficult task of facilitating cross-cultural negotiation. In this sense, non-reflective incorporation of elements of TEK can reduce to a utilitarian and hierarchical perspective in which TEK is treated as a simple toolbox that may or may not be used conveniently while maintaining an overall narrative of epistemic and ontological superiority of science. It is necessary, then, to develop educational processes that go beyond the utilitarian perspective of TEK at the service of AEK and to think about science education as a process that is concerned with the epistemological and ontological commitments of the participants. Intercultural dialogue must be accompanied by an interepistemic and interontological dialogue with the objective of not only finding convergences to facilitate dialogue, but also to recognize and understand the (epistemic, ontological and value) divergences that need to be negotiated in culturally sensitive science education processes.

## 6. Negotiating partial overlaps: classrooms as trading zones

The framework of “partial overlaps” (Ludwig, 2016; Ludwig & El-Hani, 2020) between TEK and AEK can be interpreted both as a model and a methodology. As a model, partial overlaps represent relations between knowledge systems that include overlaps in shared (epistemological, ontological, and value) commitments as well as partiality in the sense of the simultaneous persistence of substantive difference. As a method, partial overlaps can guide negotiations between epistemic communities by actively seeking out common ground for dialogue while emphasizing the need to recognize and actively engage with difference.

While the results of our study fit this overall picture, they also provide resources for a more fine-grained understanding of negotiation processes. By complementing the framework of partial overlaps between TEK and AEK with the notion of “trading zones”, we aim to add a dynamic process component both to the modeling of relations between knowledge systems and the methodology of intervening into them through educational practices.

Inspired by work in anthropological linguistics, Galison (1997) introduced the notion of trading zones to history and philosophy of science from where it has made its way into interdisciplinary debates (Collins et al., 2007) including science education (Mills & Huber, 2005). At the core of Galison’s account is the observation that “subcultures trade” and therefore create “trading zones [as] an intermediate domain in which procedures could be coordinated locally even where broader meanings clashed” (1997, 46). In Galison’s seminal research on microphysics, trading zones are mostly modern institutions such as laboratories “in which engineers, physicists, chemists, and metallurgists composed a new idiom and practice of experimental research.” Our case study takes Galison’s epistemological construal of trading zones closer to its original anthropological context by locating them in non-academic communities of the Global South.

Framing our classrooms as trading zones allows acknowledgement of the relative independence of epistemic communities of TEK and AEK while simultaneously directing the focus towards spaces of negotiation. In many ways, local practices such as the use of mato (case 1) and triplet



crops (case 2) remains independent from scientific research just as academic perspectives in ecology often operate without a direct connection to TEK. Maintaining such independence can be an explicit goal as the epistemic self-determination of local communities is sometimes the most efficient response to the continued destabilization and marginalization of TEK (Ludwig & Macnaghten, 2019). At the same time, intercultural structured classrooms constitute trading zones that create spaces for productive integration of epistemic resources such as academic and traditional understanding of ecological relations.

Thinking of trading zones as spaces for epistemically productive exchange complements the idea of overlaps between TEK and AEK. However, recognition of the partiality of such overlaps can also help to avoid a naive characterization of trading zones as harmonious places of mutually beneficial intellectual exchange. Trade is not always successful. It is not always mutually beneficial. And trade is certainly not always a non-hierarchical exchange between equals. Just as economic trade requires political economy, our case study shows that epistemic trade requires political epistemology. Trading zones are deeply political entities that can approximate ideals of non-hierarchical exchange between epistemic communities but are more commonly structured along unequal power relations from slight differences in epistemic influence to cases of outright domination (Galison, 2010; Murphey et al., 2016).

Classrooms rarely confirm to ideals of non-hierarchical exchange between TEK and AEK. Talk about “knowledge systems” is always an abstraction from heterogeneous practices and neither TEK nor AEK become incorporated into classrooms as a whole. Which parts of TEK become incorporated depends on heterogeneous factors and one persistent challenge of the marginalization of TEK is that it often enters the classroom only where it already overlaps with AEK in the sense of being seen as valid by (or even useful for) academic perspectives. Our case study reflects how this process of knowledge incorporation is shaped by hierarchies along various dimensions (Fig. 7). For example, teaching materials and the very set-up of formal schooling prioritize academic knowledge production and rarely leave substantial space for TEK (Wotherspoon, 2015). Furthermore, classroom interactions often involve more informal forms of “testimonial injustices” (Fricker, 2007) in the sense that TEK is treated as less reliable and in need of validation through AEK (see also Koskinen & Rolin, 2019). Finally, our case study also highlights the crucial role economic factors such as the pressure to give up TEK through adoption of conventional agriculture and its underlying knowledge regimes.

Thinking about classrooms in Coração de Maria and Retiro as trading zones does not only help to understand the often highly politicized structure of negotiation processes but also spaces for educational interventions that can reconfigure processes of knowledge incorporation. First, interventions can target the material teaching infrastructure through the development of new teaching materials. For example, we developed teaching materials in comic format as a result of collaborative work with teachers and researchers. The comic tells the story of Zé, a student from the region, who develops contextual solutions of problems in the community by putting into dialogue the contents of school science knowledge (AEK) and traditional knowledge of the community (TEK). Second, some of our interventions addressed more implicit forms of testimonial injustices in the sense that children were encouraged to embrace TEK in a way that does not make its value dependent on validation through AEK. For example, the value of local insect classifications for traditional agricultural practices does not depend on phylogenetic validation as it is constructed with different epistemic and non-epistemic aims (section 5.3). Third, intercultural classrooms can become spaces for synthesis of TEK and agroecology if the value of these practices (e.g. avoidance of soil erosion, food sovereignty) is clearly developed together with students despite external pressures of adopting conventional agriculture that heavily relies on monocropping, synthetic inputs, and integration in an industrialized agri-food system.

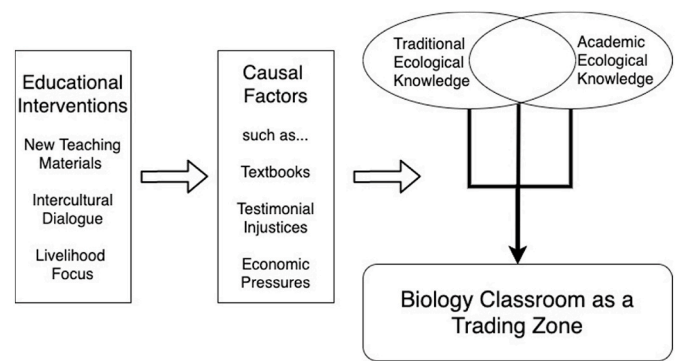


Fig. 7. TEK and AEK are represented as partially overlapping knowledge systems that are incorporated in the classroom. Intercultural dialogue requires that TEK is not only incorporated where it already overlaps with AEK. The process of incorporation is shaped by diverse causal factors which can themselves be shaped through educational interventions.

## 7. Conclusion

The aim of this study has been to develop a transdisciplinary approach for navigating the relations between TEK and AEK that triangulates (1) empirical research, (2) philosophical reflection, and (3) educational intervention. Through an ethnographic study, we have shown that TEK and AEK are related in complex ways that involve both points of convergence and divergence. Mobilizing frameworks of “partial overlaps” and “trading zones” from philosophy of science, we have shown how these complex relations can be analyzed through a nuanced epistemology that avoids misleading narratives of smooth knowledge integration or a clash of entirely incommensurable worlds.

Bringing educational interventions into this research program demonstrates the potential for action research that treats the relation between TEK and AEK as more than just an abstract philosophical puzzle. Indeed, knowledge diversity about the biological world is full of intriguing epistemological and ontological questions about different ways of producing knowledge, intervening, and classifying nature. In this sense, it is a fruitful ground for abstract philosophical debate and intellectual wonder. At the same time, it also opens new avenues for socially relevant philosophy of science (Douglas, 2010; Fehr & Plaisance, 2010) by connecting knowledge production to socio-ecological dynamics and livelihoods in the Global South. Intercultural science education can function as a mediator between different epistemologies and ontologies if it is adequately engaged with both the empirical and philosophical complexity of bringing both TEK and AEK into local classrooms.

## CRedit authorship contribution statement

**Jairo Robles-Piñeros:** Conceptualization, Investigation, Writing - original draft. **David Ludwig:** Methodology, Writing - original draft, Writing - review & editing. **Geilsa Costa Santos Baptista:** Supervision, Project administration, Writing - review & editing. **Adela Molina-Andrade:** Supervision, Writing - review & editing.

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