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ARTICLE

Intercultural Education as Dialogue Between Knowledge Systems: Elements of a Theoretical Framework

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Abstract
In this paper, we discuss elements of a theoretical framework for intercultural education as dialogue between knowledge systems, both in general terms and in the specific domain of science education. This framework synthesizes outcomes of theoretical and philosophical studies with contributions from practical experiences in artisanal fishing communities, also involving collaborative work with primary education teachers for developing and investigating educational innovations within a community of practice. Three central ideas from this framework constitute the core of the paper: an interpretation of the intercultural attitude in pluralist pragmatist terms; an understanding of intercultural education as a dialogue that involves translation as a creative, meaning-making act; and the partial overlaps approach, as a way of considering both approximations and differences between knowledge systems in three domains: epistemological, ontological, and axiological

1 Introduction

We will discuss in the paper some elements of a theoretical framework for intercultural education as dialogue between knowledge systems that has been built by synthesizing outcomes of philosophical and theoretical studies with contributions from practical experiences in action research efforts in artisanal fishing communities (see, e.g., El-Hani & Mortimer, 2007a, b; El-Hani & Bandeira, 2008; Baptista & El-Hani, 2009; Valderrama-Pérez et al., 2015, 2020; El-Hani, 2022; El-Hani & Almeida, 2022; Bollettin et al., 2023). The ideas presented here have been influenced by an immersive experience of collaborative work with teachers from a school attended by students from two fishing communities in the Brazilian shore since 2016. This is a theoretical paper and the collaborative experiences with the teachers and the outcomes of the intercultural education approaches developed with them will be presented elsewhere. But as the philosophical work underlying the

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arguments in the paper does not rely only on armchair analysis but also on reflections built while engaging with the teachers' and communities' knowledge and practices, we will begin by briefly describing some aspects of this immersive experience.

The elements of the theoretical framework have also been nourished by collaborative work between university researchers and teachers in a community of practice (CoP) aimed at planning and carrying out intercultural education as dialogue between knowledge systems. A CoP is a group of individuals with distinct sets of knowledge, abilities, and experiences who are actively involved in collaborative processes with the goal of building both personal and collective knowledge (Lave & Wenger, 1991; Wenger, 1998). A human group becomes a CoP when the shared practice becomes a source of coherence, generating mutual engagement, a sense of community, co-responsibility bonds, and the construction of a common set of knowledge, values, attitudes, actions, goals, memories, etc. (Wenger, 1998; Wisker et al., 2007; El-Hani & Greca, 2013). We have been gradually establishing in our collaborative work this coherence grounded on shared practice, such that a CoP is emerging as a springboard for mutual learning and professional development.

The CoP involves nine local teachers[1] and meets on a monthly basis, in one of the teachers' planning meetings, which occur twice a month. In these meetings, we discuss theoretical ideas on intercultural education, putting educational and teacher knowledge into dialogue, and plan interventions to be carried out by the teachers. This collaborative work is an official outreach activity by the university, and thus, the teachers can receive an official certification for their participation, which they can use to receive salary supplements from the municipality. The CoP aims at building new teaching approaches in the local school, through which the communities' knowledge and practices can find a place in the classroom, in dialogue with school knowledge; students' self-esteem as fishers' sons and daughters can be promoted; and clear connections with the school mandatory curriculum can be built.

This paper has the following structure: we will begin by introducing some ideas about education in contemporary intercultural societies. Then, we will present an understanding of interculturality that avoids a relativist interpretation committed to the "equal validity" thesis (Boghossian, 2006) and proposes, instead, a pluralist pragmatist view. Next, we will consider the idea of dialogue between knowledge systems and discuss how intercultural translation can be conceived as a creative, meaning-making act that can give room to learning from others even in cases of (radical) difference. We will present, then, the partial overlaps approach, which provides a way of considering both approximations and differences between knowledge systems in three domains: epistemological, ontological, and axiological. In our concluding remarks, we will briefly consider how we are attempting to translate elements of the theoretical framework into the reality of the collaborative work with the local teachers.

2 Intercultural Societies and Multi-edged Relationships in Cultural Contact Zones

In the wake of globalization processes, we are living in increasingly intercultural societies. In these societies, socioculturally different individuals and groups (in their intersecting diversity of ethnic origins, cultural backgrounds, genders, social classes, racial positioning, etc.; see, e.g., Lee & Luykx,

[1] It is fundamental to acknowledge here the teachers involved in such a collaborative effort: Almeir de Oliveira Santos, Andrea da Conceição Santos, Andréa Oliveira Bezerra, Charlene de Jesus Paiva, Elda dos Santos Santana, Elizângela Silva dos Santos, Genalva Santos de Oliveira, Maria José da Conceição, and Marinês Conceição dos Santos.

2006) mutually constitute one another, becoming who they are through relationships of reciprocal exchanges, conflicts, negotiation, and so forth (García Canclini, 2004).

A useful lens to understand these relationships is offered by the notion of culture, which can be conceived, following Geertz (1973, p. 5), as "an ordered system of meaning and symbols, in terms of which social interaction takes place." Cultures are necessarily realized in the situated, objective context of social relations, practices, livelihoods, and, thus, can only be understood in such a contextual, embedded coupling. They are also generally associated with "knowledge systems" built by communities as networks of agents interconnected by social relationships through which they dynamically combine doing, learning, and knowing (van Kerkhoff & Szlezák, 2016), and eventually establish practices that mediate knowledge production, transfer, and use (Cornell et al., 2013). These systems show a determinate degree of internal and practical coherence, derived from the way they develop along generations of agents dealing with situations embedded in the socio-environmental circumstances in which they carry out their cognitive and practical actions. Knowledge systems contain claims about the world showing content related to such situations and actions (not only negative claims against what other knowledge systems state), show a degree of internal coherence, are based on the practices of a community, and show pragmatic value in relation to situations influencing their development. Although this is a rather broad characterization, we contend that it should be so if we want the concept to include diverse knowledge systems, ranging from Indigenous to academic scientific ones.[2] While Indigenous knowledge systems, many instances of local knowledge systems and the academic sciences satisfy the criteria above, pseudoscientific views such as intelligent design (ID), creation science and others do not fulfil them. They lack sufficient coherence, piling up claims that contradict each other, do not show pragmatic value, and/or are mostly comprised of negative claims to what scientific views state.

To understand intercultural societies, it is also helpful to consider—alongside with Geertz's—Hall's (2006) dynamic account of culture as a continuous process of producing and rebuilding novel concepts, meanings, understandings, and ways of living in the midst of everyday changes. After all, in an intercultural society individuals and groups that use different systems of meaning and symbols are continuously mutually constituting each other in their social interactions, generating emerging understandings and ways of living that can lead to encounters and misencounters often not restricted to the symbolic domain. In the current globalized world, we often find, therefore, what Tsing (2005) calls "friction," "the awkward, unequal, unstable, and creative qualities of interconnection across difference" (p. 4). The spread of global connections entails the travel of political, economic, scientific ideas and practices—or at least their products—around the world,

[2] We use the expressions "academic science," "academic scientific knowledge," and derivatives to refer to Western scientific knowledge as typically developed and certified in academic socio-institutional systems, embodied, for instance, in universities, research centers, scientific societies, private companies' laboratories, etc. Our intention is to both ground the understanding of these knowledge systems on the socio-historical contexts in which their knowledge-producing practices take place, and to leave it open if other knowledge systems, for instance, Indigenous, can or should be described as "scientific" (as in the reference to "Indigenous science"; e.g., Snively & Corsiglia, 2001; Brayboy & Castagno, 2008; Alessa et al., 2016; Johnson et al., 2016; Whyte et al., 2016). This is a controversial issue in the philosophical, educational, and scientific literature that we do not intend to settle here. But leaving it open is more than just a way to avoid engaging in demarcation debates. It follows from our conviction that these debates are less fruitful than a different take on the problem. To focus on demarcating between knowledge systems can lead to a "divide between indigenous and scientific knowledge" (Agrawal, 1995) that positions the epistemic practices of Indigenous and local communities as alien and incommensurable with modern science, losing from sight that they also exhibit convergent practices and criteria (Ludwig et al., 2023). We are much more interested in investigating the epistemic practices, tools, and heuristics that are shared or not between different knowledge systems, based on the partial overlaps approach (Ludwig, 2016; Ludwig & El-Hani, 2020; El-Hani et al., 2022; Renck et al., 2022; see below). Our position would be entirely different, however, if we were discussing pseudosciences or scientific denialisms, in which cases we think demarcation is important.

through aspirations of universal dreams and schemes that can only be fulfilled in the sticky materiality of practical, situated, local encounters (Tsing, 2005). Thus, the aspirations and sociopolitical ambitions of a global society and market inevitably generate a rubbing with local identities, ways of life, modes of production, and knowledge systems.

In this process individuals and groups intersect in a deeper and increasing manner, to the point that encountering with each other becomes, for many, constitutive of their understanding of themselves and the world they live in. Global connections entail, then, an increasing relevance of border-crossing forms of identification. As Arturo Escobar writes, once one recognizes that ideas such as "civilization," "modernity," "development" cannot be conceived without considering the idea of coloniality and a pervasive eurocentrism, the process of bringing these ideas into concrete, objective experience

> … always creates types of "colonial difference" — encounters, border zones, processes of resistance, hybridization, assertion of cultural difference, or what have you — where dominant modern forms fail to fulfil themselves completely as such, revealing simultaneously the arbitrariness (and often brutality) of many aspects of the modern project, and the multiple assertions of pluriversality, what in the decolonial perspective is called "worlds and knowledges otherwise". (Escobar, 2018, p. 94)

Hybridizations have become increasingly central in intercultural societies marked by constant interaction between different subjects and groups, and, accordingly, border-crossing forms of identification were also empowered. While on the one hand these forms of identification are marked by contradictions and asymmetries, on the other, they put into question essentialist views of identities and differences (Bhabha, 2015), and highlight a central element of education in current times: the need that individuals build capacity to negotiate cultural border-crossing in such a manner that they are able to keep their cultural identities while constantly contacting a range of distinctive others and eventually incorporating certain aspects of other cultures with which they interact.[3] Such a cultural border-crossing takes place when students from Indigenous, local and other communities learn science, entailing the need that science education also deals with capacity-building to negotiate it (Aikenhead, 1996; Banks, 1999).

An intercultural society can be conceived as showing several to many cultural "contact zones," "social spaces where disparate cultures meet, clash, and grapple with each other, often in highly asymmetrical relations of domination and subordination," in which "peoples geographically and historically separated come into contact with each other and establish ongoing relations, usually involving conditions of coercion, radical inequality, and intractable conflict" (Pratt, 2008, pp. 7–8). Despite such asymmetrical relations in contact zones, encounters taking place in them are not one-dimensional but rather constitute multi-edged relationships. Therefore, dichotomous views of cultural contact zones are not sufficient, and more complex perspectives are needed. Not only unequal relations of power and domination take place there,

[3] We need to exercise care when appealing to the ideas of hybridization and border-crossing identities, as they may lead to, or justify, a dilution of the differences between cultures that meet with one another, or of the tensions, colonial processes, cultural erosion consequences that can take place in their contacts. To consider the context where one works is fundamental to reach a clear perspective on the potentialities and limitations of using the notion of hybridization as an interpretive lens. Consider, say, artisanal fishing cultures in the Brazilian shore, which are themselves a product of cultural contact between Indigenous peoples originally living there, African peoples brought to Brazil as slaves, and Portuguese colonizers (Diegues, 1999; Ott, 1944). They are already situated in a bordering zone, as hybrid cultural products, and remain placed in a contact zone with other cultures circulating in current societies. In this case, hybridization provides a proper lens to understand artisanal fishing communities. But the same may not be true if one is dealing, say, with an Indigenous group fighting to preserve its culture, practices, knowledge, value systems in its own territory, with more diffuse borders with other cultures, where appealing to the notion of hybridization may dilute key tensions and differences.

but also "new arrangements of culture and power" (Tsing, 2005, p. 5). Thus, when thinking of contact zones, we should be attentive both to relations of domination, subjugation, oppression, violence, conflict, and to possible emergent relationships, i.e., to the possibilities for dialogue in encounters across difference—the productive features of friction (Tsing, 2005, p. 10).

Given the central role of scientific knowledge in Western modernity as well as in the colonial and globalization processes, science education is a domain in which we can often find relations of domination towards other knowledge systems. However, we consider science education to be also a powerful tool for nourishing possibilities of new relations with knowledge that can empower local communities. These possibilities will be more frequently promoted in the science classroom if we explicitly consider how science education is often, if not typically, taught as a way of domination (Kato et al., 2023). That is, how science is often taught in an epistemically unjust way, in such a manner that all other knowledge systems or perspectives on the world are judged based on scientific epistemological criteria, turning academic science into a benchmark for the meaning and validity of everything that is known. There can be no doubt that science education can be very important for making students capable of using scientific ideas that can be indeed powerful to solve their problems and the challenges faced by their communities. But if we intend that science education truly brings contributions to local communities, we will need to teach science through a culturally relevant or culturally responsive pedagogy (Ladson-Billings, 1995; Pejaner & Mistades, 2020) that does not undermine the students' relations with their cultural backgrounds, even contributing to cultural erosion (Athayde et al., 2017), but rather build fruitful spaces for dialogue between school science and Indigenous and local cultures. We need to take in due account that while students from Indigenous and local communities are still learning school contents, they are also often holders of at least part of their communities' knowledge. This is an important reason why we need to be careful, on the one hand, regarding relations between this knowledge and what they are learning in school, and, on the other, explore the possibilities offered by their knowledge to scaffold learning of scientific and other ideas in the school curricula that can be helpful to their lives and communities.

3 Interculturality as a Key Aspect of Contemporary Science Education

In intercultural societies, it is important to consider how socioculturally different individuals and groups interact in schools and other educational settings. Education—including science education[4]—can be conceived as a space of tensions and convergences, cultural

[4] In this paper, we consider both general education and, science education when discussing elements of a theoretical framework for intercultural education. It is unavoidable that a number of arguments are built in more general terms than those specific to science education. We face a challenge related to the tensions between generality and specificity in the arguments about intercultural (science) education. On the one hand, while it is true that the issues related to interculturality bring particular challenges to science education, many of the challenges bridge between general education and specific educational domains; on the other, many of the specific challenges related to science education have to do with particular topics in this domain, as different issues will appear if we are talking about, say, biological, physical, or chemical education, and even within a field such as biology, if we are talking about, say, evolution or ecology. We opted, then, to build part of the arguments on a more general tone, part of the arguments specifically pointing to science education. For the same reason, in many arguments we consider science education in general terms, i.e., in relation to all disciplinary domains in the natural sciences. However, in some cases, we focus our attention on biological and ecological knowledge as domains of outstanding importance and fine-grained expertise in Indigenous and local communities. At this stage of our work, we intend to build a general framework, from which it will be certainly necessary to derive specific arguments considering the plurality of scientific fields and, thus, the specificities of their practices of knowledge production. There are important differences between, say, the epistemology of physics and the epistemology of biology, which may bring specificities to intercultural dialogue, but we need to leave them for future works. Similarly, non-academic cultures and knowledge systems are also plural and their specific practices may also bring differences to intercultural dialogue, which, again, we will leave for future works. Here, we will mostly focus on Indigenous and local knowledge systems.

encounters and misencounters (Canen, 1997; Ivenicki, 2018; Molina-Andrade, 2015), but these may be invisible to many educational actors. It is important to ask how science education can deal with such encounters and misencounters, especially when considering oppressed and marginalized individuals and groups. The attempt to advance responses to this concern leads us to claim that interculturality is a key notion for understanding the role of science education in contemporary societies.

In intercultural societies, schools are traversed by contact zones, spaces of friction, possibilities to enable and simultaneously exclude. Schools are spaces where students from different sociocultural backgrounds meet to learn hegemonic cultures and forms of knowledge. Learning them is important for the students, as school knowledge plays a role in their inclusion in the societies where they live. It is evident, for instance, that science learning is quite relevant to their lives in current societies. But classrooms are also spaces where knowledges and identities are constructed, colonized, and contested (Mohanty, 2003). This is a major justification for the need to consider them under the lens of interculturality.

Interculturality is central to our understanding of contemporary education no matter if we are considering an Indigenous or rural community or some megalopolis anywhere in the globe. In all schools, we find students who developed in distinct sociocultural contexts. In all schools, we witness tensions, encounters, disagreements, synergies among teachers, students, and other actors participating in educational processes. To think interculturally on such processes is also important because part of these events can remain unnoticed, silenced by the prevailing power arrangements. Then, to look at science education with an intercultural lens prompts us to ask relevant questions: How can science education handle such encounters and misencounters, tensions and synergies? What kind of science education is needed in the cultural contact zones navigated by students from different sociocultural backgrounds?

As academic work necessarily involves practices and activities based on the work of scientific communities (Longino, 1990; Erduran & Dagher, 2014; El-Hani & Reis, 2021), there is a sense in which we can think of academic science as a form of culture. In these terms, thinking of the science classroom as a locus in which different cultures interact, as a place rich in cultural contact zones, becomes a natural consequence that deserves exploration. We are urged to consider, then, how the interactions between different cultures and knowledge systems can be dealt with in the science classroom, and two important requisites come to the fore: first, that the goals of science education in the schooling process—as historically established in a given sociocultural circumstance—should be fulfilled; otherwise, science education and its actors will not be playing the social role expected of them. In particular, one central goal of science education should not be lost from sight in intercultural science education, namely, the understanding of school scientific ideas (El-Hani & Mortimer, 2007a, b), as we will argue in more detail below. Second, we need to consider what form of science education is more prone to foster the goals, aspirations, and expectations of the different communities represented in the classroom.[5] This means that, even though the goal of understanding school scientific ideas should not be neglected, how to achieve understanding and its consequences are crucial aspects to consider. Scientific contents should not be justified as part of the curriculum just because they are part of science, as if scientific literacy would be something to pursue no matter what. They need to be justified also in relation to

[5] Surely, this second requisite is much simpler to handle when schools are located in more homogeneous communities, as in the case of artisanal fishing or Indigenous ones. If we consider this requisite in more heterogeneous school settings, there will be rather complex issues to discuss about the relations between the cultures and knowledge systems present in the classrooms. We think the ideas advanced in this paper are also helpful for pondering about these more complex situations.

what a community expects of the education of its children and youth, in relation to a community's self-determination rights concerning education.

This second requisite also means that intercultural science teaching needs to be dialogical, it should give room to a dialogue between the knowledge systems represented in the classroom. But this dialogue should not be taken as merely a way of making the students learn school science better. It should be aligned with the role scientific ideas can play in relation to the goals and aspirations of the communities.

A dialogical approach to intercultural science education demands well-planned transitions from multivocal to univocal approaches, and back (Scott et al., 2006).[6] For instance, apt transitions from multivocality to univocality are necessary to properly articulate a dialogue among different students' ideas with the goal of teaching and learning about one knowledge system, namely, school science. In turn, to properly move from univocal to multivocal approaches is important for the learned ideas to make sense within students' views and lives, such that they can be brought to bear on their realities.

Intercultural education faces the challenge of creating conditions for the students to value and know the cultures from which they originate, while also knowing the culture of others and being able to cross borders between cultures (Aikenhead, 1996; Banks, 1999). Or, else, the challenge of observing one of the imperatives of an "intercultural dialogue on human dignity," as expressed by Boaventura de Sousa Santos (1997, 2001) when claiming that, once individuals and groups tend to be distributed according to competing conceptions of equality and difference, they have the right to be equal when difference makes them inferior, and the right to be different when equality makes them lose their identifying characteristics.

It is necessary to fight against the conversion of differences into sources of inequality. After all, the differences ascribed to oppressed or marginalized groups are often associated with multidimensional forms of inequality, as a consequence of a series of historical segregations configured through cultural differences and socioeconomical inequalities (García Canclini 2004). Accordingly, we may underscore the need to educate subjects for being capable of handling intercultural experiences, designing educational processes that support both the continuity of ethnic, group, cultural identities, and the access to cognitive constructs and practices that travel across cultural borders and can contribute to marginalized groups' struggles against iniquities. In science education, this challenge translates into the need to design teaching methodologies that scaffold the development of students who are able to cross borders into the culture of the (academic) sciences, becoming apt to understand them, and yet keeping their identity as members of their own cultures (e.g., Aikenhead, 1996; Cobern & Aikenhead, 1998; Costa, 1995).

4 A Pluralist Pragmatist View of Interculturality

To conceive science teaching and learning under the lens of intercultural interactions entails considering how the academic sciences and their practices relate to other knowledge systems. We will appeal here to Rist and Dahdouh-Guebas' (2006) description of unacknowledging, utilitarian, neo-colonial, paternalist, essentialist, and intercultural attitudes of science towards local and Indigenous knowledge.

[6] The reference to "univocality" and "multivocality" derives from the Bakhtinian concept of "voice" (Bakhtin, 1981), which amounts to the perspective assumed when using language, related in turn to a certain way of seeing the world.

4.1 A Typology of Relations Between the Academic Sciences and Other Knowledge Systems

Academic scientists take an *unacknowledging* attitude when they simply ignore other knowledge systems and their practices. We find this attitude, for example, when closed periods for fisheries are established without taking into account artisanal fishers' knowledge (as discussed, e.g., by Musiello-Fernandes et al. 2017; Renck et al., 2023a, b). We also encounter it in the replacement of the millennial irrigation systems used in Bali's rice fields, managed through the mediation of Hindu-Buddhist water temples dedicated to the Goddess of the Lake (Dewi-Danu), by technical-scientific irrigation systems associated with the Green Revolution (Lansing, 1991; Lansing & Kremer, 1993; see below).

When scientists extract elements of other knowledge systems that fit their own cognitive constructs, epistemology, ontology, and values to increase the stock of academic knowledge, they assume a *utilitarian* perspective, characterized by what Kimmerer (2012) calls "knowledge mining" or what Alcoff (2022) describes as "extractivist research." If the knowledge extracted is then used by academic scientists and their partners to generate patents and commodities without recognition of the intellectual property of its original holders, a *neo-colonial* attitude is present (as discussed, e.g., by Posey et al., 1996).

When a given knowledge system is regarded as requiring "updating" by the academic sciences, a *paternalistic* attitude can be identified. An example is found when traditional livestock breeding is "blended" with "modern" technologies (e.g., Theunissen, 2018).

In turn, an *essentialist* attitude can be discerned when one takes Indigenous or local knowledge as a kind of museum piece to be preserved as it is, kept apart from the influences of Western, modern knowledge and technology, due to its alleged right to remain unchanged. This ignores, however, that any human culture has been and continues to be shaped through many experiences of contact with other cultures along its history rather than being self-generating (Tsing, 2005). It is also a common element of this attitude to take Indigenous knowledge to be fundamentally better than the academic sciences by *petitio principii*.

Finally, in an *intercultural* attitude, in Rist and Dahdouh-Guebas' (2006, p. 474) own words, "science is aware that it is only one type of knowledge among others, and that knowledge is always embedded in cultural and historical settings," such that "science and local knowledge can benefit from comprehensive interaction."

By assuming such an attitude, one acknowledges that there is a diversity of knowledge systems developed in distinct sociocultural and historical circumstances, and, also, that there is a diversity of ways of knowing and related epistemologies.[7] After all, knowledge systems do not harbor only cognitive constructions but also conceptions and criteria about what constitutes "knowledge" (and/or "expertise") and what doesn't. For instance, in the artisanal fishing communities with which we work (El-Hani, 2022; El-Hani et al., 2022; Renck et al., 2022), if we ask someone with whom we should talk to know more about, say, fishing with throw nets, he or she will immediately tell which fishers would be good choices to learn from. There is a clear distinction, shared by the community members,

[7] The use of "epistemologies" in the plural reflects the view that there is not only a diversity of first-order knowledge about the world or a diversity of methods and methodological rules but there is also a diversity of higher-order reflections about knowledge and practices of knowledge creation/certification. We use "epistemology," therefore, to refer to these higher-order forms of reflection rather than merely to the institutionalized field in academic philosophy (see Koskinen & Ludwig, 2022), even though we can also use the term in the latter sense, since we think of, say, modern epistemology as a particular feature of modern philosophy, which institutionalized higher-order methodological and epistemological reflections.

between who is more and who is less versed about a certain kind of fishing practice and the associated knowledge. This distinction entails the use of certain criteria about knowing or not knowing, i.e., of a certain epistemology.

In a recent study (El-Hani et al., 2022), we investigated the epistemology of the artisanal fishing community of Siribinha, inquiring into what epistemic practices and resources for explaining phenomena they shared or not with the academic community. It was clear that the fishers had resources to distinguish between situations in which they had explanations for a phenomenon or not, indicating that they use epistemological criteria to judge what constitutes an explanation and what doesn't, or when they know or don't know something. For instance, when asked to explain why the Rufous crab-hawk (a near threatened species locally known as Gacici, corresponding to the academic-scientific species *Buteogallus aequinoctialis*) calls when the tide turns, they were quite sure they couldn't explain why, while they were equally sure they could explain other phenomena, such as the periods where the estuarine environments have plenty of Snooks.

4.2 The Problems of a Relativist Position Committed to Equal Validity

Rist and Dahdouh-Guebas' (2006) description of the intercultural attitude allows two distinct interpretations. We intend to avoid one of them while embracing the other. We avoid a relativist interpretation committed to an idea of incommensurability without qualifications, or, to put it differently, full incommensurability. It is important to notice from the beginning that "relativism" is a term used to designate a diversity of stances and, also, that "incommensurability" is used in different senses. In the philosophy of science, the notion of incommensurability was originally applied by Kuhn (1962-1996) and Feyerabend (1962) to the relation between successive scientific theories. The relativist interpretation discussed here applies, however, beyond the domain of successive scientific theories. An extension of the concept of incommensurability is found in Feyerabend's work itself, as he used it not only to discuss scientific theories, but also incommensurable frameworks of thought and action (1975, p. 271), incommensurability in the domain of perceptions (1975, pp. 225, 271) or incommensurable discoveries and attitudes (1975, p. 269). Kuhn, in turn, qualified his appeal to this notion in successive works, taking pains to distance himself from charges of relativism (see, e.g., Hoyningen-Huene, 1993; for discussions of the notion of incommensurability in Kuhn and Feyerabend, see also Oberheim & Hoyningen-Huene, 2018).

As the notion of incommensurability had its extension expanded along the years, it ended up nourishing the specific kind of relativism we worry about here, committed to what Boghossian (2006, p. 2) calls the problem of "equal validity," i.e., the idea that there are many radically different, yet equally valid ways of knowing the world. This idea has been associated with the work of a variety of thinkers (e.g., Feyerabend, 1975; Margolis, 1991; Rorty, 1991) and has also been linked to science education research, as part of proposals on multicultural science education (e.g., Ogawa, 1995). A close position is also found in the ontological turn in anthropology, in which "ontology" is often framed almost exclusively through difference, as reflected in claims of "radical alterity" and "incommensurability" of ontologies (see, e.g., Holbraad & Pedersen, 2017).

At first, the idea of "equal validity" seems to provide a straightforward reading of the claim that "science is aware that it is only one type of knowledge among others" (Rist & Dahdouh-Guebas, 2006, p. 474). But consider, on the one hand, that to recognize a

diversity of knowledge systems does not necessarily entail such an idea of equal validity. On the other, an appeal to incommensurability seems to offer a relevant ground for criticizing the assumption of universal validity of the academic sciences and for defending the diversity of ways of knowing developed in different cultures. As this is the position we take when arguing for a diversity of knowledge systems and epistemologies, and when positioning ourselves critically in relation to the claim that the academic sciences would be universally valid, we need to further consider what would be the problem with what we are calling a "relativist" reading committed to "full incommensurability." Moreover, we need to inquire into the possibility of a *via media* between the claim that there would be universal, context-free or super-cultural epistemic standards or values that would allow us to locate knowledge systems in some single hierarchy, with the academic sciences at the top, and the claim that there is a way for distinguish between better or worse knowledge choices in the face of objective states of affairs.

A major problem lies in how difficult it is, once we assume the "equal validity" of ways of knowing and knowledge systems, to justify the decisions we need to make when facing concrete situations that compel us to opt for a certain way of understanding and/or acting, among several that may be available. Another reason for concern is that the very idea of an intercultural dialogue is undermined if a notion of insurmountable incomparability or incommensurability is taken to follow from the recognition of a diversity of knowledge systems, ways of knowing, epistemologies. Similarly, any decision on how to act towards social transformation is rendered unjustifiable by such relativism since "if all forms of knowledge are equally valid as knowledge, every project of social transformation is equally valid or, likewise, equally invalid" (Santos, 2016, p. 190). Cultural relativism, as García Canclini (2004, p. 182) argues, also reduces inequalities to differences between cultures and, thus, shows important limitations in the face of a globalized, intercultural world that requires recognizing both differences and inequalities. A relativist view committed to full incommensurability is inadequate to tackle the unceasing interconnections between human groups that hold distinct forms of knowledge and are often forced to put them into dialogue, while at the same time comparatively judging them as possible frames to interpret problematic and frequently conflictive situations.

4.3 A Pluralist Pragmatist Interpretation of the Intercultural Attitude

But how could we be committed to a recognition of the diversity of ways of knowing, knowledge systems, epistemologies without subscribing to the idea of full incommensurability? Or, alternatively, how could we get around the problem of equal validity without assuming that the academic sciences would constitute a benchmark against which all knowledge systems could be measured, i.e., without being committed to epistemic injustice (Anderson, 2012; Fricker, 2007; Wanderer, 2012)?

These concerns can be mitigated through a different reading of the intercultural attitude, which assumes a distinct philosophical position, pluralist and pragmatist in character, rather than relativist (in the sense described above). Surely, one might argue that the position we will explain below is just another form of "relativism," which qualifies the idea of incommensurability. We would have no quarrels with that, provided that the content of the position we espouse is kept clear. Nevertheless, we think it is always good advice that, in order to make our ideas clear (see, e.g., Peirce, 1878), we do not use different words to say the same thing, or the same word to say different things.

The most central idea in this position is *pragmatist* in the sense of assuming that the analysis of the validity of a cognitive construction should be carried out through a *reasoning that starts from or is based on consequences*. In these terms, knowledge claims produced by distinct ways of knowing can be judged comparatively, i.e., they are not necessarily incommensurable, but this judgment should be made in such a manner that no absolute or abstract hierarchization of knowledge systems be supported. It is about maintaining, on the one hand, that knowledge claims (or systems) are incommensurable *in abstracto* (i.e., based on allegedly non-situated criteria, which could be said to be general), but, on the other, can be compared based on validity criteria situated in the frame of reference of problems established in well-defined circumstances.[8] This is the case precisely because, as stated by Rist and Dahdouh-Guebas (2006, p. 474) in their explanation of the intercultural attitude, "knowledge is always embedded in cultural and historical settings." It is because these contexts are varied, as a consequence of the diversity of natural systems with which human groups interact, according to their particular, contingent, historically established ways of living, that the different knowledge systems (including the academic sciences) can benefit from mutual interactions.[9]

A pragmatist pluralist view accepting incommensurability *in abstracto* and situated commensurability considers that decisions about what knowledge claims to use are defensible, but only in the context of situated action. Therefore, it does not amount at all to a claim that knowledge would be totally homogeneous, totally relative, and totally incommensurable. We are just claiming that there is no abstract question about knowledge commensurability that can be cogently answered, or, to put it differently, that any such question would be unanswerable because any cogent commensuration between knowledge (or, for that matter, actions) is necessarily situated.

As Tsing (2005, pp. 1–2) writes, "as soon as we let go of the universal as a self-fulfilling abstract truth, we must become embroiled in specific situations." Therefore, knowledge claims can only be compared in the friction of situations experienced in our objective lives. In these circumstances, the claim of any form of knowledge to universality is inexorably marked by the situated nature of our adherence to, and our judgments about it:

> ... even those of us who believe that some knowledge claims are better than others have difficulty in denying that even the best ones retain a certain incommensurability. This is because knowledge claims emerge in relation to concrete problems and possibilities for dialogue – the productive features of friction (Tsing, 2005, p. 10).

As Santos (2010, p. 49) writes, in this manner we can conceive of a way of being a realist based not (or at least not centrally) on a representational relationship between knowledge and reality, but on the pragmatic consequences of knowledge put to work in interventions on reality:

[8] In this manner, we have resources for the struggle against both post-truth or post-factual thinking and politics (see, e.g., Fuller, 2018; McIntyre, 2018; Farrell, 2020) and the claims of a general epistemology that denies the epistemological diversity of human cultures (Santos, 2010, 2018).

[9] We can derive from the pluralist pragmatist view expounded here the relevance of developing a curricular construct complementary to the Nature of Science (NOS), namely, Pragmatics of Knowledge (POK). Its goal would be to prompt students to recognize the diversity of knowledge systems, ways of knowing, epistemologies, and at the same time understand how they are incommensurable in abstract terms but comparable in a situated manner. We are currently working on the development of this construct and how it could be addressed in general and science education based on the conceptual profile theory (e.g., Mortimer & El-Hani, 2014). We are thankful to Boaventura de Sousa Santos for raising in personal communication with the first author an argument in this direction.

> For an ecology of knowledges, knowledge as intervention in the real – not knowledge as representation of the real – is the measure of realism. The credibility of the cognitive construction is measured by the type of intervention in the world that it provides, helps or impedes.

This style of realist thinking is characteristic of the pragmatist tradition, which harbored several versions of pragmatic realism (see, e.g., Pihlström, 1996). From the perspective of this pluralist pragmatist realism, the benchmark to commensurate knowledge claims lies in the type of intervention in the real that they allow or impede and its consequences. This is related to a basic common theme in the tradition of pragmatism,[10] in its many varieties (Meyer, 1908), namely, a strong emphasis on the practice- and discourse-embeddedness of any human cognitive construction (El-Hani & Pihlström, 2002; Pihlström, 1996). The cognizable world and any explanation, description, observation about it are necessarily conceptualized through our own practices of predication and inquiry. As these practices shape our knowledge about the world, no simple mirroring relationsh

ip between knowledge and world can ever be obtained, as it is widely accepted in philosophical thinking for many decades (Mitchell, 2003; Pihlström, 1996). This conclusion has, however, sweeping consequences. At the same time that knowledge illuminates the world, it also conceals it. In the same move as knowledge opens up certain possibilities to understand, it blocks our access to other possibilities. As Santos (2018, p. 40) argues, "any system of knowledge is also a system of unknowns." It is this recognition of such a double nature of knowledge that is taken by pragmatists as a ground for claiming that knowledge must be judged, at least in part, in terms of its consequences.

The connection between reasoning from consequences and the epistemic concern about meaning and truth has been developed in the wake of C. S. Peirce's "pragmatic maxim," according to which the meaning of a concept corresponds to the habits of action it produces:

> To develop its meaning [of a thought], we have, therefore, simply to determine what habits it produces, for what a thing means is simply what habits it involves. Now, the identity of a habit depends on how it might lead us to act, not merely under such circumstances as are likely to arise, but under such as might possibly occur, no matter how improbable they may be. (Peirce, 1878, pp. 292-293).

Or in another formulation:

> In order to ascertain the meaning of an intellectual conception one should consider what practical consequences might conceivably result by necessity from the truth of that conception; and the sum of these consequences will constitute the entire meaning of the conception. (Peirce, 1931-1935, CP 5.9).[11]

Pragmatism can be conceived, in sum, as an approach to clarify the meaning and validity of concepts and knowledge claims based on ascertaining the experiential consequences

[10] It is interesting to consider the contribution of Amerindian Indigenous knowledge to the pragmatist tradition. Even though pragmatism is often regarded as a development from Western European thinking into a distinctive philosophical school in response to experiences in the North-American wilderness, the roots and central commitments of this tradition also stem from ways of thinking found among North-American First Nations (Pratt, 2002).

[11] We follow here the common practice of citing from the Collected Papers of Charles Sanders Peirce indicating volume and paragraph numbers preceded by "CP.".

that would follow from our thoughts and actions if the claims were true, or the concepts, acceptable.

To conclude this brief exploration of a pluralist pragmatist interpretation of the intercultural attitude, we should clarify that "consequences" need to be regarded in terms much broader than suggested by any reading that reduces them to the idea of "practical utility" or "application." When considering the consequences of a thought or claim, Peirce (1878) refers to any circumstances that might possibly occur. As Rescher (1995) discusses, when Peirce referred to the practical consequences of accepting an idea or statement, he initially meant the consequences for experimental practice, but he eventually moved beyond this, treating pragmatic effectiveness as a means for the quality control of human cognition. Moreover, when reasoning about cognitive constructions based on consequences, we should consider not only the types of intervention in the world that they provide or help, but also that they impede. This latter consideration can hardly be well-captured by a reference to "application" or "utility."

Therefore, reasoning from consequences includes both the possible practical utility of interventions following from a cognitive construction but also their sociopolitical, ethical, heuristic, and other implications. Besides, consequences should be judged in both a negative and a positive sense, i.e., not only in terms of what they provide but also of what they hinder. This broad view on consequences is far-reaching: when we evaluate knowledge claims, we should also take in due account their consequences in terms of what they provide or impede in ethical and sociopolitical terms (say, is this a cognitive construction that favors prejudice? Does it impede violations of human rights? Does it make room to racist attitudes? Does it sustain or reinforce relations of domination, oppression, discrimination, or exploitation? Does it foster or support the struggle against oppression?). Moreover, we should bear in mind the heuristic power of knowledge claims or concepts as "thinking devices" (Lotman, 1988, quoted by Wertsch, 1991, pp. 73–74), i.e., in terms of their consequences for the generation of novel meanings, to how able are we to make our ideas clear, and so on.

Finally, while reasoning from consequences is, as its very designation indicates, a form of reasoning, it is not to be treated—at least not necessarily—as detached from an affective dimension. The recognition that our knowledge claims are always embroiled in specific situations that populate our objective lives entails the importance of using epistemologies and methodologies that are sensitive to the context, situation, relationships, and identity of the social actors engaged in pondering about a cognitive construction. It also points to the need to engage all senses, to draw on aesthetic/artistic as well as on practical/instrumental resources, on both reason and affect, as we find in conceptions of knowledge responsive to the inextricable connection between feeling and thinking (e.g., Freire, 2019a; Nunes, 2021; Santos, 2010, 2018).

5 Dialogue Between School Science and Other Knowledge Systems

The intercultural attitude entails the importance of enabling dialogue between knowledge systems, especially in contact zones like schools. Considering schooling contexts, this translates into intercultural education conceived as a way of supporting dialogue between knowledge systems in the classroom, both in general and in the specific domain of science education (El-Hani & Mortimer, 2007a; Baptista & El-Hani, 2009; Valderrama-Pérez et al., 2015, 2020; El-Hani, 2022). The dialogue between school knowledge and the

culturally grounded knowledges that the students bring to the classroom favors meaningful exchanges among the subjects from different cultural backgrounds that meet in the school spaces (Candau, 2006), as well as between their own views and scientific knowledge.[12] Science education and, in particular, biological education deserve special consideration in this respect, since several opportunities for dialogue, as well as challenges, emerge in the relations between these educational domains and Indigenous and local knowledge. It is not sufficient, however, to tackle only science or biological education, without considering how they relate to intercultural aspects of the educational processes, as these more general aspects will cut across any attempts to deal with knowledge dialogue in the domain of biological and scientific subject matters.

5.1 Dialogue and the Goals of Science Education

One of the central goals of science education is the understanding of scientific ideas, which can bring to different communities more equal footing in relation to processes that marginalize them. Different Indigenous communities, such as the Yup'ik, Iroquoian, Pankararé (Kawagley, 1990; Martin, 1995; El-Hani & Bandeira, 2008), among several others, express the desire that their youth learn about multiple worldviews and become able to operate within both the Western societies and Indigenous communities. Many Brazilian Indigenous peoples, for instance, have fought and keep fighting for inclusion in several levels of the educational system, including public universities (e.g., Lima & Barroso-Hoffmann, 2004; Grupioni, 2013). They recognize the need that their children master both their own culture and other cultures, in order to move across cultural contact zones without facing alienation from communities and families.

It is important to clarify our claim that a central goal of science education is teaching and learning for the *understanding* of school scientific ideas (El-Hani & Mortimer, 2007a, b). We are not defending that it is sufficient that students understand science "without believing that anything that is claimed in science … should be accepted as true" (Hoffmann, 2007, p. 690). We do argue, however, that one should be careful about the idea that schools should assume the goal of "changing what students believe about reality" (cf. Messeder Neto & Rosa, 2022, p. 11, n. 1),[13] since clashes between their worldviews and school science may happen, with worrisome consequences for students' perspectives and attitudes, and also for the very success of science teaching (see Cobern, 1996; El-Hani & Mortimer, 2007a, b). But this does not entail simply giving up any influence that schooling may have on how students think of reality. What we argue is that a science teacher should not take directly shaping students' beliefs as her goal, but rather focus on understanding and then leave for the dynamics of the students' cognitive systems what belief or acceptance outcomes will emerge or not as a consequence of learning.

[12] Students will also bring to the classroom alternative conceptions that are not derived from their Indigenous or local knowledge systems, sometimes even conceptions shared by children from several different cultural backgrounds (see, e.g., Gilbert & Watts, 1983). We are not considering these alternative conceptions here because they fall outside the scope of the paper. Undoubtedly it is important and interesting to consider such alternative conceptions when dealing with classroom dialogue, but our focus is on the relations and dialogue between ideas from other knowledge systems and school science and/or academic science. While it is a relevant topic of inquiry to explore how can we relate dialogue between knowledge systems and alternative conceptions the students can bring to classroom discursive interactions, we will leave it to be dealt with elsewhere.

[13] All original texts in other languages than English have been freely translated by the authors.

A crucial aspect here is that, even though belief does not always follow from understanding, understanding typically yields belief and typically guides action (Smith & Siegel, 2004, p. 554, 564. See also Evnine, 2001; Adler, 2002). We do not argue, thus, that the science teacher should simply lose from sight the relevance of students' acceptance of ideas presented in school science. Our argument is more subtle: she should aim at understanding, taking into account that we tend to accept propositions we understand, unless there are reasons that counter this tendency. When belief or acceptance does not follow from understanding, there may be important sociocultural reasons for that outcome, which are likely connected with clashes between scientific claims and fundamental ideas in the students' ontological, epistemological or axiological standpoints, worldviews, experiences, and/or modes of being in the world. The central point in our argument is that these conflicts deserve close attention; hence, the caveat that science teachers should not take as a goal to try to shape the content of students' beliefs directly. While teaching for understanding, a good science teacher will offer the reasons for the scientific statements at stake, and if the students are successful science learners, they will likely understand both the statements and the reasons why they are worthy of belief. Nevertheless, they are still in a position in which they may reject those reasons, and a putative factor leading to that result is a clash with their worldviews, which as science teachers we should not neglect (El-Hani & Mortimer, 2007b, p. 699).

We cannot lose from sight, however, that while many Indigenous and local communities have expectations in relation to schooling that entail understanding cultural ideas present in mandatory curricula, they typically also wish that schooling takes place in a way that does not alienate their children from their own culture. As we argued above, this entails that teaching must be planned so as to allow for appropriate turning points from multivocality, in which several voices are mobilized and duly considered in the classroom, to univocality, in which the teacher strives for creating favorable conditions for the students to understand the perspective of school science concerning a given subject matter (Scott et al., 2006). In this process, we consider that the voice of the academic sciences is to be treated according to the intercultural attitude conceived under pragmatist pluralist rather than relativist lens, as explained above. Therefore, a transition from multivocality to univocality must be built in a culturally-responsive manner, giving the students access to understanding scientific ideas without alienating them from their own culturally grounded ideas (e.g., El-Hani & Mortimer, 2007a; Robles-Piñeros et al., 2020). Moreover, it is important that opposite turning points also occur, namely, from the univocality that allows for students to understand scientific ideas back to a multivocality that puts these ideas into contact with their own knowledge, especially in relation to the situated problems faced by their communities.

Some caveats are necessary for a proper understanding of what we propose regarding intercultural science education. It is important to bear in mind, for instance, that the intercultural attitude is not about equal times and emphasis on different knowledge systems in the places where one is supposed to learn about one of them, such as the science classroom. To give an example, to argue for teaching about creationism in the science classroom—i.e., to treat creationism as part of a science learning goal, not as part of the classroom dialogue—makes as little sense as to argue for preaching about Darwinism in, say, a Christian cult. What follows from an intercultural attitude is the importance of dialogue between distinct knowledge systems, which means that, if creationist students are in the

classroom, a dialogical approach between school scientific knowledge and the form(s) of creationism they accept is relevant. In this case, we are dealing with the issue of recognizing and duly considering different knowledge systems without assuming that all need to be taught in every context.

A second issue concerns ideologies[14] that do not qualify as knowledge systems and should not be participants of classroom dialogue at all (unless they are taken as objects of criticism), as in the case of pseudosciences or denialisms that raise rather different questions than those concerning relationships between knowledge systems. The intercultural attitude—as we understand it—*does not* entail the proposal of a classroom dialogue, say, about intelligent design (ID) or climate denialism, as they do not qualify as knowledge systems.

We are also *not* claiming that science education should be limited to community goals, as we rather think of intercultural education—as stated above—as aiming at creating conditions for students to value and know both the cultures from where they originate and the cultures of others (including Western modern scientific culture), while being able to cross borders between cultures. We *do not* think that the interest and relevance of community members knowing scientific ideas (say, about biology, chemistry or physics) should not be considered. What the view on science education we endorse *does entail* is that a proper justification for including scientific ideas in the curriculum should take in due account the community's goals, expectations, knowledge, and practices, and that, while teaching school science, a teacher needs to put it in dialogue with ideas from other knowledge systems that are present in a community. The contention is that the goals of intercultural education and of the communities themselves should be fulfilled too, not only the goals of science teaching.

Let us briefly consider an example of classroom activity that emerged from our collaborative work with the teachers in the CoP, in order to explore the interplay between communities', teachers', and researchers' goals. This is an activity that resulted from the teachers' proposal that the way the fishers move a boat down the beach and manage to enter the rough sea in front of the communities, which was shown in an ethnographic movie made by the research team (available at: https://www.youtube.com/watch?v=bYDReP9roIo), could be used to explore some mathematical and physical notions in the classroom. A colleague who was working with the CoP at the time, Orlando Aguiar Jr. (Federal University of Minas Gerais, Brazil), proposed, then, a sequence of playful activities involving the equilibrium of rigid bodies. The intention was to promote classroom activities that allowed the students to explore physical knowledge, in the sense proposed by Kamii and DeVries (1993), i.e., activities in which the children were encouraged to respond to practical challenges by manipulating objects, while verbalizing the solutions found. The activities sought a parallel with the situation of moving a boat on the sand, but with playful and practical materials to be manipulated by the children.

A first activity involved the notion of center of gravity. The students were challenged to balance a ruler using just one finger and, then, to repeat the activity adding an eraser to one of its ends. A parallel was made with how a fisher sits at an end of the boat while another fisher rotates the boat in order to move it down the beach. The second activity involved balancing a torque scale, which consisted of a ruler with holes in which rings of the same weight could be placed. The challenge was to balance a ring on one side of the scale using

[14] We use the term "ideology" in the sense of "cultural beliefs that justify particular social arrangements, including patterns of inequality" (Macionis, 2010, p. 257).

two rings on the opposite side. Evidently, we did not intend to teach about the concepts of center of gravity or momentum, but just to approach the children's intuitions by means of actions on physical objects that were inspired by how the fishers move a boat down the beach and into the sea. In general, the children continued to hold that the boat becomes lighter when someone seats at one of its ends, a common explanation among the fishers. But the activities allowed them to conceive another way to look and talk about the situation: sitting on the edge of the boat changes the place where the boat support point lies on the sand, thus making it easier to rotate the boat using a longer lever. When we were developing the intervention with the teachers in the CoP, they suggested that we could also use the torque scale to teach the students about multiplicative operations, such that they could learn, say, that the products of 3×1 and 1×3 are the same by manipulating situations in which they placed three rings in the first hole in the ruler (3×1) and one ring in the third hole (1×3). Teachers' goals regarding mathematical teaching were thus also included in the activity.

These exploratory activities brought contributions to the development of some mathematical and physical notions by the children, without any intention that they might learn scientific concepts about levers, forces, etc. Surely, goals of science teaching were central to these activities. But the same was also true of understanding the embodied and situated knowledge involved in how the fishers move the boat down the beach and into the sea, which fulfils communities' goals concerning the recognition and appreciation of their knowledge. The activities allowed considering that this is knowledge in its own right, which can be put into dialogue with school science, while not being translatable into academic (school) knowledge without loss of content. After all, physical and mathematical understanding does not replace the fishers' know-how. Even if we clearly grasped the mathematical and physical ideas involved in their movements, we would not be able to move the boat down the beach or into the sea by simply using those ideas; rather, we would need to develop the same know-how, and we would not do it by attending to the propositional knowledge from physics or mathematics. As the oldest fisher in Siribinha, Jonas, told us, we learn fishing knowledge and practices "in the school where you learn by doing with me" (https://www.youtube.com/watch?v=bYDReP9roIo), meaning that this is learning that happens by participating in the practices such that after observing what an experienced fisher does, you can also engage in the practices so as to develop the embodied and situated knowledge associated with them.

5.2 Considerations on the Meaning of Dialogue Between Knowledge Systems

Given all these complexities, it is important to provide a clear formulation of the idea of dialogue between knowledge systems. To do so, we will rely upon the works of Enrique Leff, Paulo Freire, and Boaventura de Sousa Santos.[15] There are meaningful connections between these authors. Freire's work, for instance, has been a major inspiration for Santos' approach to the epistemologies of the South (see, e.g., Nunes, 2021).

Leff (2003) argues for the need to build a dialogue based on a rationality that seeks to understand the other without subsuming cultural differences under a supposedly universal background knowledge and without translating "the other" in terms of "the same."

[15] A number of other authors also bring contributions to the conception of dialogue between knowledge systems, as an element of intercultural education. See, e.g., Pérez-Ruiz & Argueta Villamar (2011), Aman (2018), Baptista (2018), among several others.

This entails the need to understand and work with differences between the knowledge systems placed in dialogue, avoiding both epistemic injustice (Anderson, 2012; Fricker, 2007; Wanderer, 2012) and homogenization, which would mean establishing a domination of one knowledge system over the others. Furthermore, the challenges concerning intercultural translation that will be discussed in Sect. 6 are implied in Leff's argument, given the idea of understanding the other in its own terms.

In Freire's (1992; 2002; 2019a, 2019b; 2020) conception of education, dialogue plays a central role as a way of unveiling realities and engaging the subjects in educational processes that can make them more critical, reflective, and autonomous. For him, learning is a practice based on active and participatory approaches, involving the discovery of *generative words* and *themes* based on the vocabulary of the subjects. Generative words and themes, alongside with culture circles as venues for learning and knowing, are the main tools for the dialogical-problematizing or liberating education at the core of Freire's pedagogy. This pedagogy, influenced by Dewey's conceptions of active learning and intelligent action, is counterposed to what Freire calls "banking education" (in Portuguese, "educação bancária"), characteristic of a hegemonic form of education committed to an instrumental conception of learning and knowledge.

Freire treats knowledge as arising from inextricable relations between reason and affect (Nunes, 2021). In the dialogue between teachers and students, as well as among the students themselves, he insists on the need that differences be exposed, listened to, respected, and taken seriously, such that all the actors are prompted to learn reflectively along the educational process. Through reflective learning, they can become subjects of their own lives, be able to read the word and the world, an outcome that Freire calls "conscientization" (in Portuguese, *conscientização*; Freire, 2020). This is related to a pervasive aspect of Freire's work, a tension between struggle and dialogue, between the denunciation of all forms of oppression and the advocacy and enactment of a vision of democracy strongly influenced by Dewey's pragmatist philosophy (Nunes, 2021). Freire's conception of education is not limited to schooling and, in fact, embeds a broadly political and critical view of the school as an institution as well as of teaching practices, both considered in connection with the social circumstances in which they are situated. His overall intention was to bring about a broader view of what counts as knowledge and advocate for teaching that favors cultural border-crossing without denying difference, a "dialectical overcoming in which the different preserve what is essential in their differences and share what brings them together in their similarities" in the search for a "universally plural" society, as Peroza, et al (2013, p. 479) argue, echoing Santos' (1997, 2001) intercultural imperative mentioned above.

Finally, the idea of dialogue plays a central role in the epistemologies of the South, as elaborated by Santos (e.g., 2010, 2018). They are conceived as a "set of epistemological interventions that denounce the suppression of knowledges caused over the last centuries by the dominant epistemological norm,[16] that value the knowledges that successfully resisted and the reflections they have been producing,[17] and that investigate the conditions for a horizontal dialogue between knowledges" (Santos & Meneses, 2010a, p. 7). This dialogue is what Santos (2010, 2018) calls "*ecology of knowledges.*"

The central ideas of the epistemologies of the South are related to a broader epistemic and political process that has been ongoing since the 1990s and brought to the fore the notion of the "Global South," largely as a successor to "Third World," after the end of

[16] This is related to what Santos calls the "sociology of absences.".

[17] This is related to what Santos calls the "sociology of emergences.".

the Soviet Union (Levander & Mignolo, 2011). This notion is not defined in strictly geographic terms, but is rather delineated by a "political economy of the South" (Dwivedi, 2001) that reflects global and local patterns of exploitation of labor and natural resources. However, beyond this economic character, the Global South has clear epistemic consequences. Campos (1991), for instance, introduced the South as a place of epistemological reorientation through the notion of *sulear* (from *sul* and *orientar*, meaning South and to orient in Portuguese), which refers to alternative map projections that invert the Northern gaze. The term "sulear" was popularized by Freire (1992), who regarded the epistemologies, ontologies, and historical subjects of the Global South as integral parts of "a geopolitical horizon in which the construction of political and educational praxes for liberation and decolonization takes place" (Barbosa, 2022, p. 626). Santos' proposal can be situated, then, within a broader dynamics fostered by *sulear* as an act of epistemic reorientation that has been embraced by scholars of the Global South through a variety of concepts such as Epistemic Decolonization, Southern Epistemologies, or Epistemologies of the South (e.g., Cruz, 2018; Escobar, 2016; Fúnez-Flores, 2023; Mungwini, 2017; Santos, 2010, 2018). On the one hand, all such concepts express a recognition of the Global South as a space of "epistemic oppression" (Dotson, 2014), while also recognizing, on the other, the Global South as a space of philosophical reflection and political action.

The construction of a horizontal dialogue between knowledge systems in such a space of philosophical reflection and political action depends on taking into account that it operates within the field of the consequences of an "*epistemicide*," i.e., the suppression of social practices of knowledge production that contradicted colonial interests, carried out through the interventions of Christianity, colonialism, capitalism, and, also, Western modern science (Santos, 2010, 2018). As a consequence, "a lot of social experience has been wasted and the epistemological, cultural, and political diversity of the world has decreased" (Santos & Meneses, 2010b, p. 10). Epistemicide is by no means a fact of the colonial past, but continues to be part of a project of homogenization of the world, which obliterates cultural differences and has been deepened by the process of hegemonic globalization. It is no coincidence that our current times are marked by a great threat to Indigenous, peasant and other communities, with the erosion of important portions of the global cultural diversity (Cámara-Leret & Bascompte, 2021; Fernández-Llamazares et al., 2021). The loss of Indigenous knowledges and languages, for instance, has a critical role in relation to important cultural bases for our survival and life quality, as illustrated by medical knowledges, which are more threatened by epistemicide than by biodiversity loss (Cámara-Leret & Bascompte, 2021). It is not, however, a matter of loss only in the domain of knowledge, but also and especially an ontological loss, an erosion of perspectives on the world and on existence, which ends up undermining the very meaning of the lives of many peoples, including ourselves (see, e.g., Escobar, 2016).

An ecology of knowledges opposes what Santos (2010, 2018) calls "abyssal thinking," which operates through abyssal lines separating human groups according to colonial, patriarchal, heteronormative, religious, and other dimensions. Insofar as these lines have been constituted in an extremely violent way (physically and symbolically), separating a human world from a supposedly non-human, or sub-human world, the separation effected by them not only generates social exclusion but produces a dehumanization. The abyssal lines present a cognitive dimension, as they also separate a knowledge taken to be unique, either religious or scientific, from an alleged absence of knowledge in the colonized and/

or subjugated territories. The recognition of the epistemological dimension of the abyssal lines implies that global social injustice and global cognitive injustice are closely related.

An ecology of knowledges constitutes, then, the construction of post-abyssal thinking, which takes as a point of departure the idea that the diversity of the world remains devoid of an adequate epistemology. We need to build a renewed understanding of how the diversity of knowledge systems is intertwined with a diversity of epistemologies (see Koskinen & Ludwig, 2022). The recognition of the epistemological diversity of the world comes hand in hand with the necessity of refusing a general epistemology that denies this diversity by treating modern science (or philosophy) as a ruler or benchmark for measuring the validity of all other knowledge systems. This is of key importance when we consider the current situation of democratic states. As Serpa (2006, p. 111) writes,

> by disqualifying the other, his voice, his wisdom, his knowledge, his perception of the world, I empty any meaning that may exist in the advocacy for dialogue, I empty any meaning that there may be in the word democracy. I empty any meaning that may exist in weaving a curriculum that have difference as a value. Difference conceived here as that deep respect and awareness of the existence of the other and the legitimacy of his or her place in the world, a respect that allows me, even in the conflict, even in dispute, to establish a space for negotiation, for listening to the other, and in this process listening to me through the other.

It is not a matter, however, of simply opposing the cultural and cognitive legacy of the academic/modern sciences, or of providing support to some anti-science sentiment or movement. As Santos (2010, p. 48) writes, "in the ecology of knowledges, as a post-abyssal epistemology, the search for the credibility of non-scientific knowledge does not entail the discrediting of scientific knowledge." Just as the epistemicide that followed the European colonial expansion amounted to a huge waste of knowledge and experience, the denial of the heritage of modern scientific thinking in terms of knowledge and practices would be yet another massive and far-reaching waste. The advocacy for the diversity and plurality of knowledge systems and epistemologies only demands questioning the idea of the uniqueness of some single knowledge system or way of knowing as exclusively rigorous or valid. Consider, for instance, that the very way of knowing that was assumed to be exclusive and unique must be integrated into a plural recognition of the diversity of knowledge systems and epistemologies. After all, the academic sciences are certainly part—and an important part—of an ecology of knowledges. It is just that they aren't all the ecology. What a post-abyssal epistemology implies is, rather, a counter-hegemonic use of academic knowledge, which can be fostered by dialogue and mutual learning between academic and other communities.

6 Intercultural Translation as a Creative, Meaning-making Act

Intercultural translation plays a central role in dialogue between holders of distinct knowledge systems but also faces important challenges. One difficulty lies in the problem of full incommensurability, which Santos (2010, p. 52) interprets as a strategy of an abyssal epistemology to discredit the very possibility of an ecology of knowledges by postulating the impossibility of a translation that might allow for mutual intelligibility of different languages, cognitive experiences, knowledges, symbolic universes.

But it is important to consider that Western epistemology also includes schools of thought not committed to this view of incommensurability, for instance, the pragmatist pluralism discussed above. The idea of entirely incommensurable knowledge systems has been questioned in its very coherence by different philosophers (e.g., Davidson, 1984; Putnam, 1981). An example for counteracting the idea of full incommensurability is found, for instance, in Kohn's (2013) discussion of how the Runa of Ecuador upper Amazon conceive of forests as thinking agents. If a non-Runa reader feels this idea to be either fascinating or perplexing, this feeling will arise precisely from the ontological difference between the Runa's and his or her own view, provided that he or she reserves "thinking" for a much narrower set of beings such as humans and some other mammals. This also means, however, that the idea of thinking forests is not so incommensurable that Kohn's descriptions become unintelligible to non-Runa readers; otherwise, they could not even regard them as either fascinating or perplexing. The same conclusion may also follow from examining how the Western intellectual heritage has also harbored radical expansions of the realm of cognition, as shown, say, by current controversies about plant intelligence and cognition (Adams, 2018; Segundo-Ortin & Calvo, 2019; Trewavas, 2003).

From a political perspective, claims about fully incommensurable worlds entail political risks since they undermine the possibility of fruitful interactions between heterogeneous social actors, especially in intercultural situations. They raise similar risks and difficulties in educational processes. Abyssal lines between metropolitan and colonial territories or between the Global North and the Global South are made insurmountable by such claims, and the same is true of the divide between the epistemological, ontological, and axiological standpoints developed in those territories. The corollary is that, just as epistemological universalist views do, positions committed to the idea of full incommensurability also entail the divide between Western scientific and Indigenous knowledges denounced by Agrawal (1995). They create borders that not only can be criticized due to their artificiality, but also, and especially, contribute to marginalize Indigenous and other knowledge systems in the domains of politics, education and social practices, based on an assumption of intractable differences (Hunn, 2014).

Hence, the deeply political nature of intercultural translation, as a way of struggling against the silencing of other cultures and knowledge systems through colonialism and globalization, and, thus, as part of the construction of another form of globalization, post-abyssal, and counter-hegemonic. Intercultural translation can be seen as one way of giving room to the voices of those who have been and continue to be silenced, marginalized, and oppressed through colonization and globalization. We need to be aware that dialogue may fail not because people do not have what to say, but because they do not know how to say, because their aspirations may be unspeakable. It is challenging, then, to make silence speak in a manner that brings about autonomy, not the reproduction of silencing (Santos, 2007, p. 55), and intercultural translation—not as a unilateral but as a shared experience—can unveil ways of making dialogue flourish.

6.1 The Nature, Prospects, and Limits of Intercultural Translation

In view of this political dimension, it is important to consider the nature, prospects and limits of intercultural translation, or, as Tsing (2005, p. 18) writes, the messiness of the work of translating. As Quine (1960, 1969) discusses, all translation is indeterminate and ontological relativity is inescapable because, when we translate from one language or, we add, from one knowledge system to another, there are no precise mappings of entities,

properties, relations, etc. This is so because different languages and knowledge systems are related to distinct categorical schemes, different practices of predicating the world that cut it up differently. Therefore, when one translates from one language or knowledge system to another, translation will be always both representation and misrepresentation (Tsing, 2005, p. 275).

But to develop functional relations between different knowledge systems and their epistemologies, ontologies, and value systems, their holders will need to dialogue about their views of the world. They need to maintain and care for relationships and co-responsibility bonds along shared experiences in order to make any progress towards mutual understanding. This dialogue entails a continuous process of intercultural translation that is creative of novel meanings on all sides of the interaction (El-Hani, 2022). As the holders of distinct knowledge systems try to understand each other, mutually translating their perspectives along the shared experience, their understandings do not remain the same, but are transformed through the very process of translation.

As Viveiros de Castro (2004) argues, a "good" intercultural translation allows others' concepts—and, we can add, their practices too—to deform and subvert the translator's own conceptual (and practical) toolbox. This possibility is enhanced by a method attentive to what he calls "controlled equivocations": "to translate is to situate oneself in the space of equivocation and to dwell there" (p. 10). In a later work, Viveiros de Castro (2015, p. 7) relates the idea of controlled equivocation to Salmon's concept of ontological delegation (2017), meaning "… that the anthropologist is forced to take his/her own ontological assumptions out of the strongbox and risk their robustness and transportability by letting them be counter-analysed by Indigenous knowledge practices."

As the term is used by Viveiros de Castro, "equivocation" is not the same as "error," it is not opposed to "correct" or even "true" translation, but rather to an idea of "univocality." Equivocation is controlled when we remain aware of multivocality, i.e., that even when we and others committed to a distinct categorical scheme are apparently saying the same words, we are still saying different things. Using Bakhtin's (1981) notion of voice, despite the same words being uttered, still we have two different voices in negotiation. Controlled equivocation means to avoid assuming univocality, which would amount to simply silencing the other. Once we are aware of the unceasingly different voices that are maintained through the translation process, we may find avenues for what Viveiros de Castro (2004) calls "productive misunderstandings." This is an important outcome of intercultural translation, which can challenge our own conceptual and practical toolboxes. Mutual learning can be unleashed, then, by such productive misunderstandings.

Keeping equivocation under control in the process of intercultural translation, we and others (who use some distinct categorical scheme) may eventually learn to speak together about some shared, emergent perspective. But this does not necessarily mean that we reached some consensus since sharing a perspective can also include disagreements. In this case, however, we will be in a better position to know where we disagree, to rest content in coexisting with our disagreements, and to share experiences and realities in a trustful and truthful manner.

We think, thus, that intercultural translation can be conceived as a process of dialoguing and negotiating that requires mutual engagement and sharing of experiences and practices, while also entailing that all participants be open to the subversion of their conceptual and practical repertoires, to the process of listening to themselves through the other. From this process, new arrangements of relations and power may emerge, novel settings in which we can eventually come to speak together from and about fresh, emergent perspectives or standpoints unfolding from the shared experience and the subversion of our distinct toolkits. In this dialogical process, the Other of Others will remain other, and neither we nor

they will be saying what we were saying before. Nevertheless, the most important question concerns what novel things we may be saying together, once deformed and subverted by one another. Or, to put it differently, what novel forms of "cultural cohabitation" (Wolton, 2004) we may find.

6.2 Intercultural Translation, Relational Humility, and the Expansion of Cultural Cohabitation in a Pluriversal Science Education

Through intercultural translation, shared cultural spaces can be expanded in their reach not only through recognizing alterity, but, above all, through engaging with it. As Santos (2018) discusses, this expansion of the alterity space (or of cultural cohabitation) requires that we consider non-Eurocentric concepts—such as *ubuntu*, *pachamama*, *buen vivir*, among others—and this brings to the fore the importance of dialogue between knowledge systems in a diversity of sociopolitical contexts, including schools. A transition to a "world in which many worlds can fit",[18] as advocated by the Zapatista Army of National Liberation (In Spanish, *Ejército Zapatista de Liberación Nacional*, EZLN), or to a pluriverse, as Escobar (2016, 2018) writes, appears as a necessity. In particular, it is a necessity due to the monolithic idea of "World" or "Universe" postulated by Western modernity that spread around the globe by means of colonization and, more recently, globalization. Through this monolithic idea, a literalist interpretation of the Western ontology as establishing what things out there really are was spread throughout the globe, demoting other ontologies to a status of, at best, mere metaphors, narratives, legends, or at worst, nothing but superstition, nonsense, misconception.

To challenge this literalist interpretation, with its symptoms of naïve realism and ethnocentrism, is truly important. Ontology concerns a humanly structured conceptualized reality and, thus, cannot be sharply separable from epistemology (El-Hani & Pihlström, 2002). And, as there are many practices of predication and inquiry into reality, which means that there are many possible ontologies used to conceive of it, justifying literalism about our own ontology and denial of other possible ontologies is quite hard.

As Putnam (1994, p. 302) argues, no description of the world is the world's or Nature's own. Rather, ontological commitments depend on the conceptual frameworks within which they are made, and these frameworks depend in turn on human purposes and interests that inform how we interpret reality. When we build ontologies within our knowledge systems, we are not copying a language- and theory-independent world, but rather weaving a world-picture in which factual and conventional aspects are inseparable from one another (Putnam, 1994, pp. 250–251).

As we interpret it, the advocacy for a world where many worlds fit does not entail that one needs to embrace some solipsist view according to which there is nothing out there that we could call "real," but just worlds constructed by us, humans. The idea of worlds built by distinct practices of predication and inquiry, which generate different ontologies, can be sustained without being committed to such a solipsist view. A pragmatist realist view, for instance, explicitly avoids this commitment. And when the EZLN refers to a *world* in which many *worlds* can fit, they are denying both literalism about any ontology and any view according to which all that exists are human constructions.

[18] In Spanish, "un mundo donde quepan todos los mundos." See "Palabras de la Comandancia General del EZLN en el Acto de Inicio del Primer Encuentro Intercontinental por la Humanidad y contra el Neoliberalismo," July 27, 1996, retrieved April 14, 2024, from http://palabra.ezln.org.mx/comunicados/1996/1996_07_27.htm.

Once we accept the subversion of our conceptual and practical toolkits by a different ontology constituted through different ways of experiencing and knowing reality, we may become more open to see the limits of our own ways of knowing and experiencing, something that would be harder if we stayed clung to a literalist reading of our own ontologies. In this manner, we may be more open to explore the lights cast by other knowledge systems on experienced reality, in a more investigative attitude than the one we would assume by simply sticking to our own views as THE truth about reality. This is a key lesson, to our understanding, of intercultural translation as a way of subverting our readings of the world.

A pragmatist view allows for opening up such avenues. As it conceives of categorical schemes as dependent on human practices of predication, it displaces the idea of believing from the center of our concerns. It is not about believing or not in an ontology, in a given categorical scheme. When we talk to someone committed to another ontology or categorical scheme about how she sees the world, it does not matter if we believe it or not, if we see the world the same way or not. To focus on questions of belief leads us just to the imposition of ontologies on one another, and this does not unveil a possibility of learning. Rather, we can open up an avenue for learning when we focus not on believing, but on an attempt to learn from the perspective of the other, taking her seriously and without losing from sight equivocation. The question is: What can we learn when we dig deeper in the space of difference, of equivocality, between us and the other? From this perspective, we can explore a different ontology, a different categorical scheme as a way of learning, and, as we pursue this learning, we may be eventually challenged to rethink our own conceptual and practical toolboxes.

The Brazilian journalist Eliane Brum beautifully expresses this idea of learning that can be unleashed by taking seriously and digging deeper into the perspective of the Other in terms of "listening" (in Portuguese, *escuta*), conceived by her as the main tool of a journalist:

> Before reaching another person, I seek to empty me of myself – my worldview, my beliefs, my prejudices. It is obvious that this emptying is not complete, because it is impossible to abandon an entire cultural body. But the move is fundamental. It is what makes me allow that the narrative of the other occupy my body as a narrative of the other, and not as a narrative of the other distorted by that which my beliefs or my prejudices do not allow me to listen. If it is not like that, I do not reach this other experience of existing. (…). My body, me, is an active mediator of another voice. It is evident that, in turning this voice into word written by me, the delicate mediation will be present. It is the narrative of the other, the experience of the other, the words of the other after passing through my body. But my body is not an absolute void through which the narrative of the other passes without being altered by the experience of passing through me (Brum, 2021, p. 60).

It is due to these dynamical changes of narratives that, when two holders of distinct knowledge systems truly listen to and try to understand one another, the outcome may be the creation of novel meanings to what they are saying through their voices. This meaning-making process can generate learning if we allow it to transform our own conceptual and practical repertoires.

Such learning from mutual engagement and intercultural translation is important for a transition to a "world where many worlds fit" or pluriverse. After all, when aiming for such a transition, we are before the challenge of opposing what Law (2015) calls a "One-World World," i.e., a world where there is supposedly one single valid voice. This One-World World has been spread and keeps spreading through Western modernity and globalization,

which took for themselves the right to be "The" World and, thus, submitted all other worlds to their own terms, or, even worse, relegated other worlds to inexistence, whether through genocide, dehumanization, or the denial of any knowledge they harbor.

What to say of science education from this standpoint? Science education is typically committed to a One-World World perspective, and when we consider it in relation to the idea of a transition to a pluriverse and an ecology of knowledges, a key problem emerges: how to teach science in the context of a world where many worlds fit, how to make science education pluriversal without losing from sight—given the very counter-hegemonic role that science education can play in an ecology of knowledges—the understanding of school science as a learning goal? Or, else, how to teach science in a way that human groups exert their right to be different when equality makes them lose their identifying characteristics and their right to be equal when difference makes them inferior?

We think that if we develop "relational humility," a key virtue discussed by Vrinda Dalmiya (2007), we will be better prepared to develop scientific education as an endeavor that can vindicate the intercultural stances discussed here. That is, we may be, on the one hand, more capable of giving students the opportunity to access ways of thinking and understanding the world provided by the academic sciences, to which they may rarely have a good chance to engage, overcoming a difference that contributes to disempower and marginalize them. But on the other hand, we may also be more capable of developing science education in a manner that it does not become a factor leading to cultural erosion and loss of identity.

Dalmiya seeks inspiration in the *Mahābhārata* to propose the idea of relational humility, a "complex virtue" amounting to the "self-ascription of ignorance along with other-ascription of important knowledge":

> The more we realize what we know, the more we are aware of how much more we do not, but need to know, and, along with this, comes a realization that there are others who do know what we do not (Dalmiya 2007, p. 310).

As discussed by Dalmiya herself, relational humility is fundamentally distinct from the Socratic epistemic humility, which advises that a wise man should be recognizant of the fact that the more he knows, the more there is that he does not know. Socratic humility operates only at the individual level. Relational humility is distinct because it explicitly acknowledges that what one does not know others will (or at least may) know, and, thus, motivates epistemic practices that attend to relationships between knowers. Accordingly, as Dalmiya (2007, p. 314) argues, "educating for relational humility actively uses that acknowledged self-ignorance to ascribe knowledge to others." In this manner, relational humility, as a disposition to recognize others as proficient knowers, grounds "an active intellectual and social engagement with others" (Dalmiya, 2007, p. 311), encourages dialogue between knowers who recognize the possibilities and limitations of their own understanding as well as of others' understandings. When conceived as having the goal of promoting relational humility as a virtue, education may have as an outcome the cultivation of agents who both have a realistic assessment of what they know and recognize their own ignorance and epistemic limitations, in such a manner that their self-ascription of ignorance can become part of a process of empowering others.

Alcoff (2022) includes the development of relational humility - as an epistemic value - as one of the four corrective epistemic norms she proposes for avoiding extractivist research. The other epistemic norms introduced by her include acknowledging the incompleteness of all knowledge and aiming for developing functional relationships across divergent epistemologies. All these are equally important norms for intercultural education as a dialogue between knowledge systems, as proposed here. After all, they lead us to engage

with other knowers in an epistemically motivated manner, taking them seriously even when they diverge from us, and thus open up a space for mutual learning that is deeply necessary for a pluriversal science education that can fulfil the goal of giving the students an opportunity to understand scientific ideas while making room for a world where many worlds fit.

When we become committed to these norms and objectives, we find ourselves in the middle of a struggle to build schooling processes marked by an intercultural attitude, which look for ways to make silence speak in a manner that brings about autonomy (Freire, 2002). This is a struggle against global cognitive injustice and a search for possible spaces for intercultural dialogue. We consider that such educational processes are necessary to engage with the diversity of knowledge systems and epistemologies that are often involved in encounters and misencounters in our current intercultural societies. If we consider the role of scientific knowledge in modernity and in the contemporary construction of a globalized world, it will be clear that a dialogical engagement with other knowledge systems and epistemologies is a central aspect of science teaching in the friction of local societies with globalization. This struggle demands interventions in the education of science teachers and natural scientists. To incorporate an intercultural attitude towards the diversity of knowledge systems and epistemologies entails inciting researchers to modes of inquiry and teachers to modes of teaching that are more critical in relation to developmentalist views that straightforwardly connect the academic sciences to supposed progress and improvement to diverse communities. These views assume a paternalistic position that often neglects the risks, losses, and inequalities to which many human groups have been and continue to be subjected due to such a march towards "progress" and "development," often associated with the values of capital and the market (Lacey, 2014, 2016).

7 Partial Overlaps

A recognition of the possible outcomes of intercultural dialogue should not blind us to its limitations and pitfalls. There are important concerns related to proposals of intercultural dialogue or other frameworks for collaborative initiatives aiming at "knowledge co-creation" or "coproduction," "co-leadership," "co-management," "multi-stakeholder approaches," "participatory action research," "participatory design," "upstream engagement," "transdisciplinarity," "knowledge integration," and so on (e.g., Davidson-Hunt et al., 2012; Gavin et al., 2015; Wolverton et al., 2014).

As an example, consider the concerns about the limitations and adverse effects of integration projects in the field of conservation. Among others, Nadasdy (2003) puts forward an influential critique of optimistic visions of knowledge integration that often obscure differences between social actors and groups and thereby reproduce hierarchies between scientists and local communities in the negotiation of practice and policy. While holders of other knowledge systems are often challenged to prove the value of their knowledge by showing that it holds up to the methodological and epistemological criteria of academic researchers, academic knowledge and ways of knowing are not commonly regarded to be in need of validation through compliance with criteria from other knowledge systems. This is a source of what has been called "testimonial" or "epistemic injustice" (Anderson, 2012; Fricker, 2007; Wanderer, 2012), and contributes to practices that only recognize other knowledge systems as, at most, a source of data for academic research, while ignoring their aspects that challenge the assumptions of academically trained scientists.

To neglect limitations and pitfalls in attempts to bridge knowledge systems, to put them into (intercultural) dialogue, to engage them in co-creation, coproduction, co-management efforts may make us reproduce utilitarian or even neo-colonial attitudes towards knowledge systems other than the academic sciences, in which aspects incompatible with the ontological and epistemological commitments of the latter are simply ignored. In this manner, what is compatible with these commitments may be appropriated by academic scientists through knowledge mining (Kimmerer, 2012) or extractivist research (Alcoff, 2022), with total neglect of the integrity of the knowledge system at stake.

As Ludwig and Poliseli (2018) have argued, this situation can be described as a dilemma between assimilation and division. On the one hand, critics of overly optimistic integration, bridging, dialoguing ideals, like Nadasdy, are correct to point out the danger of downplaying differences between knowledge systems and, therefore, obscuring unique features of diverse forms of knowledge. On the other hand, overly pessimistic accounts of fully incommensurable knowledge systems are equally problematic from both theoretical and political perspectives, as discussed above. Here, the key role of an epistemological approach offering reflections on issues of power, legitimacy and saliency in knowledge bridging and dialogue comes to the fore. These are issues that may be overlooked if not explicitly addressed from philosophically consistent frameworks. However, as discussed by Rathwell et al., (2015), the epistemological issues related to bridging knowledge systems are among the least discussed in the relevant literatures.

Hence, the importance of developing epistemological and methodological frameworks that take in due account both the possibilities and limitations of intercultural dialogue, knowledge coproduction, transdisciplinary processes, and alike (Ludwig, 2016). When considering such relationships between knowledge systems, we cannot disregard complex philosophical questions about their prospects and limits. Recently, Ludwig and El-Hani (2020) summarized these questions in terms of four challenges, focusing on the relations between Indigenous/local knowledge and academic knowledge. First, there is the *epistemological* challenge that Indigenous/local communities and academically trained scientists often rely on very different methods for producing and validating knowledge, from spiritual norms for engaging with nature to computational modelling of ecological dynamics (see, e.g., Wilson, 2008; Kovach, 2009; Marlor, 2010; Chilisa, 2012). Second, there is the *ontological* challenge resulting from the commitment to different frameworks to understand experience and think of reality (e.g., Ellen, 2016; Ludwig, 2018a), as illustrated by anthropological accounts describing how the Runa of Ecuador's upper Amazon conceive of the mental life of plants and forests (Kohn, 2013), or how the Māori worldview ascribes to a river the status of a person (Hutchison, 2014). Third, there is the *ethical* challenge that these epistemic and ontological commitments are intertwined with different value systems (e.g., Anderson, 1996; Wolverton et al. 2016), which entail, for instance, contrasting ways of thinking about the moral responsibilities of human, non-human, and other-than-human agents (Lien & Pálsson, 2019). Last but not least, there is the *political* challenge that holders of distinct knowledge systems are often placed in very different power positions, with unequal force to defend their epistemological, ontological, and ethical perspectives (Nadasdy, 1999, 2003, 2005; Ludwig, 2016), in either power struggles or collaborative practices.

To tackle these challenges, Ludwig (2016) developed in the ontological domain an approach to the relations between knowledge systems that search for "partial overlaps." Later, Ludwig and El-Hani (2020) extended it to the domains of epistemologies and value systems, and also considered how an analysis of partial overlaps can lead to a fruitful understanding of the political dynamics among social actors and groups placed in different

power positions. In this approach, one analyzes the relations between knowledge systems in terms of their convergences (*overlaps*) and divergences (*partialities of overlap*) in the ontological, epistemological, and value dimensions. On the one hand, it is proposed that an analysis of ontological, epistemological, and axiological overlaps can uncover common grounds or standpoints for collaboration and mutual learning, opening up a space for shared experience, intercultural translation, knowledge coproduction, and so forth. On the other, an analysis of significant differences in ontologies, epistemologies, and values can foster reflection among researchers, Indigenous and local communities, teachers, and other social actors about their normative and political positionings in connection to the diversity and relations between distinct knowledge systems. Such a reflection can provoke, then, an engagement with the construction of a political philosophy of intercultural relations, which may contribute to the fairness and quality of transformative transdisciplinary processes. Moreover, a thoughtful analysis of partialities of overlaps between knowledge systems can inspire ways of learning from (radical) difference through intercultural translation, as discussed above. All in all, the partial overlaps framework creates conditions for shifting from a recognition of difference to the search for convergences that can offer a point of departure for dialogue between knowledge systems, for attempts at intercultural translation, and for efforts to deal with distinct ontological, epistemological, and axiological positions without losing from sight the integrity, autonomy, and self-determination of different cultures and knowledge systems.

The partial overlaps framework offers a way of identifying the complementarities and contradictions, the common platforms and alternative perspectives in intercultural and interpolitical translation that Santos (2018, p. 59) presents as a necessary counterpart to the ecology of knowledges. The idea of an intercultural translation that is also interpolitical is particularly important when we consider an education aiming at fostering the autonomy and self-determination of students and their communities. After all, it highlights that intercultural translation is not an exercise apart from social struggles, but should be organically intertwined with them, striving for transforming the cultural and epistemological diversity of the world in a capacitating factor for the subjects and groups to engage in the struggles themselves (Santos, 2018, pp. 59–60).

When inquiring into partial overlaps, it is important to take into account that ontological, epistemological, and axiological commitments codetermine one another. For instance, the way we understand existence and how we divide what we assume to exist into categories (i.e., our ontology) influence how we set out to build and validate knowledge, while the knowledge we construct influences what we assume to exist and how we categorize it. This means that we are never able to refer to overlaps that are only ontological, epistemological, or axiological. Therefore, to frame an inquiry on partial overlaps as ontological, epistemological, or axiological is, above all, a methodological decision on how to approach the issue of convergences and divergences between knowledge systems. When we start looking for, say, partial overlaps in epistemology, ontological standpoints and value commitments will appear intertwined with epistemological criteria and cognitive constructions, as it will become clear in the examples below.

7.1 Ontological Overlaps

Let us begin by exploring partial overlaps in ontology. We can do so by considering, for instance, the frequent finding of ontological convergence across cultures and knowledge systems in studies on the biological knowledge of a diversity of peoples and communities

that seem to agree on the boundaries of many biological species (Ludwig, 2016). This finding provides a different angle for investigating cross-cultural relations among ontologies than the one dominating current anthropological theory since the "ontological turn" (e.g., Holbraad & Pedersen, 2017), which emphasizes differences between cultures corresponding to cases of radical alterity. If, instead of focusing on radical alterity, we start from small-scale ontological differences, say, concerning categories of animals and plants, we can adopt another ("bottom-up") approach that is complementary to the more common anthropological "top-down" strategy that proceeds from the most salient cases of deep ontological difference (Ellen, 2006; Hunn, 2014).

Tzeltal Maya and zoologists, for instance, refer to the same animal when they talk about jaguars, even though they use rather distinct cognitive constructs to think about the animal they call Balam and *Panthera onca*. This shared reference to a particular animal is an example of what we call "ontological overlap." To explain this ontological convergence, there is no need to be committed to a burdensome idea of natural kinds that might cut reality at its joints (Khalidi, 2013; Slater, 2015; Ludwig, 2016, 2018a, b). A simpler and more convincing explanation can be found in the recognition by the Tzeltal Maya and zoologists of a shared cluster of properties that allows them to single out the same entity in their rather different experiences and knowledge systems. Think, say, of how salient a jaguar is and how salient it is the spotted pattern of its fur. It is not difficult to perceive that this can lead zoologists and Tzeltal Maya to identify similar properties or ascribe shared attributes to jaguars, which may underlie the ontological convergence. This does not mean, for sure, that there are neither properties ascribed to *Panthera onca* exclusively by Western zoologists, say, a certain number of chromosomes, or a certain geographical distribution, nor properties identified only by the Tzeltal Maya, say, a particular relation between the droppings they find in a specific spot and the presence and movements of Balam in the forest, or the hunting habits of local Balam populations (Fig. 1).

This may suggest that to find ontological overlaps would mean to translate from one culture or knowledge system to another with no indetermination or ontological relativity. We consider that this is not the case, given the limits of intercultural translation. To find an overlap does not mean to uncover some straightforward translation across knowledge systems, but is rather an interpretive move through which some ontological (and/or epistemological, and/or axiological) convergence is proposed.

Consider, for instance, Quine's (1960, 1969) example of a linguist-ethnographer learning a language in an alien land. After repeatedly seeing a native saying "Gavagai" when rabbits pass by, she writes down in her field notebook "rabbit" as a translation to "Gavagai." That is, she finds what we call an ontological overlap. But—Quine asks—how could one know if "Gavagai" really refers to rabbits as some sort of persisting whole, rather than to parts of rabbits or temporal stages of rabbits or some specific behavior rabbits exhibit? In fact, when the linguist-etnographer leaps from the class of stimuli to which the native reacts by saying "Gavagai" to the conclusion that he or she is referring to a rabbit as a persisting whole, she is assuming an ontological similarity between her own referent and the native's referent, namely, that the native is sufficiently similar to herself in how he or she interprets nature and has a general term for rabbits too, rather than a general term for stages or parts or behaviors of rabbits. It is clear, then, that the ontological overlap she finds is interpretive all the way through.

Furthermore, as Almeida (2013, p. 12, n. 13) reminds us, pragmatic truth does not eliminate ontological ambiguity. The linguist-ethnographer and the native will consistently use "rabbit" and "Gavagai" in the same pragmatic encounters with the world and, even so, their ontologies may still differ despite this pragmatic agreement. Moreover, many cases

of overlaps are much more complex than ontological convergences like the one described above, making the interpretive move much more explicit, as we will see below when considering examples of epistemological overlaps.

Yet, cross-cultural ontological convergences may provide a basis for collaborative practices, mutual engagement and learning, even knowledge coproduction by holders of distinct knowledge systems. In this manner, novel meanings may be produced, through creative acts of intercultural translation, which may foster renewed ways of understanding the natural and social reality that may be shared by heterogeneous social actors. Furthermore, in this process of dialogue and mutual translation, silenced understandings may come to light and marginalized communities may find empowering voices. That is, once we reason from consequences, we can identify fruitful pragmatic consequences of an effort to find partial overlaps, despite the indetermination of translation between knowledge systems.

Let us exemplify how ontological overlaps can establish fruitful contexts for mutual engagement and learning by considering findings from our fieldwork in the fishing communities of Siribinha and Poças (see Ludwig & El-Hani, 2020; El-Hani et al., 2022; Renck et al., 2022, 2023a). Consider, for instance, *Buteogallus aequinoctialis*, a near threatened species (BirdLife International, 2023) (in English Rufous crab-hawk) that is ontologically convergent with the local species Gacici. Can we learn novel things about this animal by putting academic knowledge into dialogue with the local fishers' knowledge?

We learn from the fishers, for example, that Gacici calls when the tide turns, as expressed in a local saying: "Gacici cantou, a maré vazou" (in free translation, "Gacici sang, the tide turned"). These calls are used by the fishers as an indication that the tide will be low after some time and they need to retrieve the fish captured in their nets. Even though there is limited academic literature about this hawk species,[19] we can learn from general claims about hawks in academic knowledge. For example, we can infer that the presence of the species in the estuary where the fishing communities are situated is a bioindicator of the good conservation status of the local mangroves, since this hawk is a specialist top predator, or that, as it is common among hawks, Gacici is likely to hunt in couples. If we now consider both fishers' and academic knowledge, we can make novel inferences that would not be possible from each knowledge system in itself. For instance, we may conjecture that Gacici calls when the tide turns to signal to a conspecific the availability of crabs for foraging. Possibly, the calls are used as signals shared by a couple, as some raptors are known to form lasting couples that hunt together. This is a new, worth testing hypothesis derived from a dialogue between fishers' and academic knowledge. Such a mutual learning is fruitful, but one can be certainly justified in saying that the benefits in this case are mostly for the academic researchers. Below we will discuss other examples with clear mutual benefits.

As an example of a partiality of ontological overlap, we can consider two species of sandpipers recognized in the local taxonomy: the small and large sandpipers (in Portuguese, *Maçarico-pequeno* and *Maçarico-grande*). If we examine their relationships with species recognized in academic knowledge, we will see that they correspond to eleven such species. In this case, we do not find ontological convergence or overlap, but a partiality of overlap related to a more general phenomenon. The terms "lumper" and "splitter" have long been used to describe cases of different distinctions in diverse taxonomies: considering a given set of species, splitters name a greater number of distinctions in the set than

[19] In a Google Scholar® search using the academic scientific name for the species, carried out in October 27, 2020, without any restrictions on publication date, we retrieved only 43 works dealing with different aspects of its biology.

lumpers (Berlin, 1992; Berlin et al., 1981). In the case of the sandpipers, fishers are lumpers in relation to academic scientists, who split the fishers' category small sandpiper into the academic scientific species *Actitis macularis*, *Arenaria interpres*, *Calidris alba*, *Calidris pusilla*, *Charadrius collaris*, and *Charadrius semipalmatus*, while the category large sandpiper is split into *Numenius hudsonicus*, *Tringa melanoleuca*, *Tringa semipalmata*, *Pluvialis squatarola*, and *Limnodromus griseus*. It is interesting to perceive, however, that the fishers' taxonomic categories are empirically valid, as these eleven academic scientific species are indeed distributed in two size classes. It is just that the fishers do not classify sandpipers with the same purpose as academic scientists, namely, to inquire into phylogenetic relationships, which leads to a fine-grained classification of sandpiper species.

We saw above that one can learn novel things by putting academic knowledge in dialogue with fishers' knowledge when overlaps are found. But would it be possible to also learn from such a dialogue in cases of partiality of overlaps? Interestingly enough, this seems to be the case. From our interviews with fishers in Siribinha, we learnt that if the animals they feed upon become scarce, sandpipers will leave the estuary. But we observe that while some sandpiper species (belonging to both local categories, small and large sandpipers) are found in the estuary only in the summer and do leave the place in the winter, others are found there all year long, something that the fishers also know. If we now consider an idea from evolutionary biology, namely, that species that are very similar in resource use (i.e., show substantial ecological niche overlap) tend to undergo character displacement along evolution (i.e., natural selection favors divergence in their characters—in morphology, behavior, physiology, etc.—such that niche overlap decreases), we can raise another novel, worth testing hypothesis from a dialogue between the knowledge systems: the observed seasonality of sandpiper species in the estuary can be explained by winter resource scarcity and the species that stay there all year long are the superior competitors, while the inferior ones undergone character displacement and migrate when resources decrease. But, again, academic scientists are obtaining the benefits from this interaction, not the fishers.

It is time, then, to consider a case in which a study on partial overlaps lead to a dialogue that brings benefits to fishers. In an inquiry into the local taxonomy and biological knowledge about fish in Siribinha, Renck and colleagues (2022, 2023a, b) found both overlaps and partialities of overlap between academic and fishers' knowledge systems. They found, for instance, that fishers are splitters in relation to academic scientists (who are, then, lumpers) in their taxonomy of snooks (locally called Robalos). As a case in point, academic scientists lump into a single species, *Centropomus undecimalis*, at least three different species identified by the fishers, namely, "Robalo comum/normal/verdadeiro," "Robalo espalmado/espada," and "Robalo suvela" or "Robalão."

The most relevant partiality of overlap found in this study concerned a mismatch between the local fishers' knowledge on the spawning period of different fish and shrimp species and the fishing closed season legislations included in the Brazilian environmental policies for protecting marine fauna, by which they should abide. Based on this finding, Renck and colleagues (2023a, b) advocate for the inclusion of fishers' knowledge into policy-making decisions about fisheries conservation and sustainable use, through participatory processes. This opposes their marginalization by academic scientists and policymakers

who assume an unacknowledging attitude towards the knowledge held by fishermen and fisherwomen, which is reflected in policy decisions that are taken without considering this knowledge.

In this manner, a dialogue between fishers' and academic knowledge can bring benefits to the fishers themselves, as the use of their knowledge to improve conservation practices and legislation empowers their participation in decision-making that affects their lives (Renck et al., 2022, 2023a, b). As discussed by Vasques and Couto (2011), the participation of distinct social actors, including fishers, in the implementation of legal measures provides a basis for more inclusive negotiation of fisheries management, which may lead to more effective conservation measures, as shown by the better outcomes reached by using Indigenous and local knowledge in the management of local artisanal fisheries rather than centralized, top-down management (Begossi, 2008).

That a subversion of power relations affecting Indigenous and local communities and knowledge systems is possible is shown by the political fight of Indigenous whalers in Alaska against the ban on bowhead whales' (*Balaena mysticetus*) hunting, based on a census carried out by academic scientists that estimated that less than 3000 animals remained in the population (Huntington, 2000). As a consequence of their struggle, a general hunting ban was replaced by a sustainable harvest quota for those whales in 1977. The whalers disputed the census, claiming that the fact that the scientists used visual counting methods led to an underestimation of the whales' population, since they had missed the animals migrating under the ice. Their criticism was taken sufficiently seriously that a new census was made, incorporating local knowledge about the whales' migration behavior. In this manner, a more accurate estimate of the bowhead whales' population was obtained, ranging from 6000 to 8000 animals. The fact that the whalers were heard both had practical implications for conservation management and brought benefits to the Indigenous communities. The benefits that Indigenous and local communities can reap from looking for partial overlaps in order to bridge knowledge systems and promote mutual learning become clear in this case.

Once the fishers we work with are recognized as knowledge producers that can bring important contributions to conservation and management, it is more likely they will be heard in decision-making affecting their livelihoods, say, about closed season regulations. Another relevant benefit resulting from a dialogue between fishers' and academic knowledge systems that explores partial overlaps is found in the inclusion of such a dialogue in the classrooms attended by the children from the fishing villages, through our collaboration with local teachers using the conceptual framework for intercultural education discussed here (El-Hani, 2022; El-Hani & Almeida, 2022; Silva, 2022).

7.2 Epistemological Overlaps

Ludwig and Poliseli (2018) developed the idea of partially overlapping epistemic toolboxes to analyze epistemic resources that are shared or not by holders of different knowledge systems in their reasoning about and understanding of the natural and social world. For instance, Indigenous, rural, and many other communities are perfectly capable of building explanations for biological and ecological phenomena, employing explanatory strategies that are both convergent with and divergent from the epistemic practices used by academic communities.

Lansing's (1991) study of Balinese rice farming offers an example of how a nuanced expertise about complex causal systems is by no means an exclusive feature of the

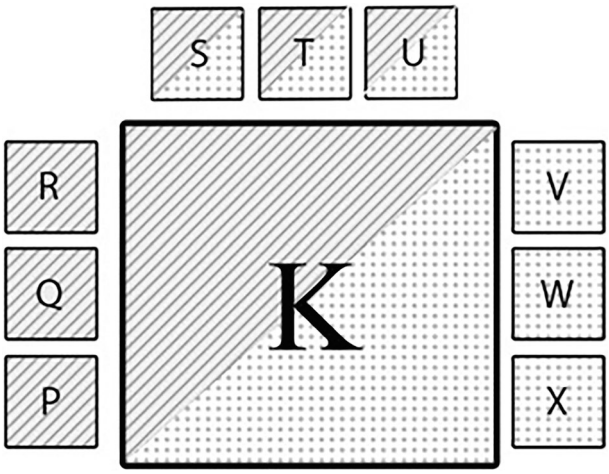

Fig. 1 Ontological overlap between two knowledge systems about a taxonomic item *K*, to which holders of each system co-refer based on a shared cluster of properties, *S*, *T*, and *U*. Properties *R*, *Q*, and *P* and *V*, *W*, and *X* are recognized by holders of one knowledge system but not holders of the other (From Ludwig, 2016)

academic sciences or modern societies. This is a classical case study about how complex Indigenous and local knowledge can be and, also, about its marginalization for the sake of modernization, in this example, of agricultural practices that would allegedly bring about development and benefits for local communities but ended up producing rather distinct effects.

Such a modernization was imposed on the Balinese rice farmers when the so-called Green Revolution was embraced by the Indonesian government in the early 1970s. The government enforced dramatic changes in rice farming, which involved, among other features, the replacement of traditional varieties of rice with new cultivars that promised quicker maturation and higher yields. Achieving these yields also required a profound transformation of local agricultural practices, which had to incorporate intensive use of fertilizers and pesticides while abandoning traditional cropping and irrigation practices. These practices were based on millenary hydrological, agricultural, and religious knowledge, with the central participation of priests from Hindu-Buddhist water temples dedicated to the water goddess Dewi-Danu. The new agricultural approach mandated continuous rice cropping, with a new cycle starting immediately after the harvest, and entailed disastrous consequences to the local farmers, threatening their livelihoods, as it caused water shortages and pest outbreaks. Harvesting decreased to less than half of what was produced under the millenary management practices. These disastrous outcomes repeated in subsequent harvests, the Green Revolution agronomical intervention was eventually abandoned, and the rice farmers returned to the previous agricultural system.

Lansing's investigation of Balinese local knowledge focused on the role of the water temples in coordinating a complex system of irrigation and cropping. His analysis of water management and pest control organized around millenary Hindu-Buddhist practices provides a clear illustration of how local knowledge can be capable of identifying processes involved in complex ecological dynamics and intervening in them through adaptive management strategies. One of Lansing's core findings was that pest control through Balinese local knowledge was largely achieved through synchronization of fallow periods that prevented the spread of animals such as rodents and insects, which could become agricultural pests, as well as of bacterial and viral diseases. By replacing the coordinating functions played by the network of water temples by a system of immediate replanting after harvest,

Green Revolution engineers created a desynchronized cropping schedule in which "migrating pests moved across the landscape consuming one harvest after another" (Lansing, 1991, p. xxii).

Complex relationships are involved in how water management by the water temples takes place. For instance, the synchronization of irrigation and fallowing schedules might create water shortages during peak irrigation demands. Water temples played, then, a very complex role of fine-tuning the water flow in a way that created sufficient synchronicity to control pests but sufficient variation in irrigation schedules to avoid water shortage. Lansing's work provides strong evidence that the coordination based on the Hindu-Buddhist water temples was actually responsible for successful water management and pest control, and its demise due to the intervention based on the Green Revolution indeed led to the disastrous consequences to Balinese rice farming.

The failed reformation of rice farming in Bali was a consequence of (scientistic) abstract judgments about the allegedly absolute superiority of academic knowledge in relation to what the engineers and government officials regarded as merely magic and superstition, derived from what they disparagingly called the "cult of rice." There was no in-depth, situated analysis of how appropriate was the millenary system of irrigation and cropping coordinated through the temples, or of the possible consequences of its replacement by a new scientifically-based irrigation and cropping system. However, as Lansing and Kremer (1993) showed through computer simulations, the synchronization of irrigation and fallowing schedules managed through the practices organized around the water temples was the most efficient possible. It was, in fact, more efficient than the technical-scientific irrigation and cropping system introduced in the 1960s, what explains the failure of the intended "modernization" of Balinese rice farming. This shows how local knowledge holders in Bali used epistemic resources partially overlapping with those used by academic communities, for instance, building complex causal understandings that allow successful intervention in the natural world, while relying upon a rather distinct ontological framework.

Another example of epistemological inquiry based on the partial overlaps framework is found in our study on how the fishers from Siribinha and academic scientists reason in causal terms and build explanations for natural phenomena (El-Hani et al., 2022). In order to elicit during semi-structured interviews causal explanations that are part of local knowledge, scenarios were used, describing regular phenomena the fishers observe in the place where they live, based on data from ongoing ethnographic studies in the community. Here, we will consider just two scenarios, one concerning the periodic disappearance and reappearance of a bivalve (locally called Massunim, corresponding to the academic scientific species *Anomalocardia brasiliana*) from the estuary, and another about the periodic occurrence of a phenomenon that some fishers call "Robalo water," in which snooks become so abundant in the estuarine waters that the fishers mostly focus on capturing them.[20]

For the first scenario, a widely shared causal explanation was found among the fishers. They explain that the disappearance of the Massunim is due to the influx of freshwater into the estuary caused by rain upstream the river, since this animal live in the estuarine brackish waters but cannot survive in freshwater. The bivalve reappears, then, because not all of them die when freshwater invades the estuary. Some remain buried in the river bottom mud and, when the rain decreases upstream and freshwater is washed away by the sea water entering the estuary (as the fishers say), the Massunim goes up from the mud and reappears

[20] For other scenarios and more details on the methods and findings of the study, please refer to the original paper (El-Hani et al., 2022).

in the river bottom. We find, in this manner, a shared epistemic resource in the fishing and academic communities, namely, the use of causal explanations to account for and reason about a natural phenomenon.

The case of the Robalo water shows that one can find, among the fishers, multi-causal, complex explanations, involving both facilitating and inhibitory factors (Fig. 2). One of the factors is, again, the influx of freshwater into the estuary, which makes the Robalos leave the refuges where they develop after being born in the mangroves—as the fishers know—protected from predators and fishing. The fish move, then, towards the ocean following patches of plant material, which offer them additional protection as they go down the river. Another factor mentioned in the explanation is the fact that the estuarine waters become muddier when it is raining upstream, making it more difficult for the fish to see the fishing nets, increasing the likelihood that they get caught. A third factor is the "burning water," an expression used by the villagers to refer to the bioluminescence observed both in the estuarine waters and in local beaches, which they attribute to jellyfish. This is a common phenomenon in Brazilian estuaries, related to ctenophores (locally identified as jellyfish) and microorganisms, which takes place especially in the summer, during the spring tides, and is more visible when the night is darker. As the fishing nets sparkle with the burning waters, they are more likely to be seen by the fish, which manage to escape from capture. There is also an interaction between moon phase, bioluminescence, and the visibility of the nets. When the moon is full, the causal influence of bioluminescence is smaller than during the new moon, because the full moon makes it harder for the fish to see the dim bioluminescent sparkling in the nets. Finally, a fourth factor is the variation in tide amplitude, as Robalos enter the estuarine waters and move towards the mangroves to reproduce during the spring tides.

If we relate these multi-causal explanations to debates about mechanistic explanations in the philosophy of science, we can discern additional overlaps between the epistemic practices used by academic scientists and fishers. There is little agreement on a general definition of "mechanistic explanation," but for our purposes it is sufficient to refer to the minimal account of "mechanism" proposed by Illari and Williamson (2012, p. 120), according to which a "mechanism for a phenomenon consists of entities and activities organized in such a way that they are responsible for the phenomenon." Our findings show, then, how local fishing knowledge can harbor explanatory practices that overlap with academic scientists' practices, such as that of building complex ecological mechanistic models. Fishers explicitly articulate a diversity of entities and activities to explain how they together produce the "Robalo water" phenomenon.

Applying Illari and Williamson's account of mechanisms to the Robalo water's explanation, it is clear that the fishers explicitly identify all three components of (1) entities and activities, (2) organization, and (3) responsibility for the target phenomenon. They explain the phenomenon by mentioning several entities and activities, such as the inflow of freshwater, the moon phases, the spring tide, the bioluminescent animals, etc. Second, these entities and activities are described as an organized set of interacting elements (Fig. 2). Finally, the fishers clearly interpret these factors causally: the visibility of the fishing nets, for example, is not merely assumed to be correlated with the Robalo water, but is rather treated as a causal factor: Robalos get caught because they cannot see the nets. It is even the case that they seem to point out to different causal pathways, involving distinct sets of interacting factors, that can lead to the same phenomenon.

It is important to bear in mind, however, that the mechanistic model shown in Fig. 2 is an intercultural translation of what the fishers told us. When we find overlaps between how fishers and academic scientists explain phenomena, we are pointing to similarities between practices we use in academic knowledge and practices they use in their local knowledge that can be interpretatively regarded as so similar that we should open up a space for taking seriously what the fishers know, for instance, how they explain phenomena. We should seriously consider how their understandings and explanations need to participate in decision-making processes, especially those resulting in policies that affect their lives, and how their participation can lead to advances that might not be possible from the standpoint of other knowledge systems.

To briefly point to a partiality of overlaps in the epistemic resources used by fishers and academic scientists, we can mention the use by the former of essentialist explanations that refer to the natural places of certain animals. They argue, for instance, that certain fish species stay in the river after entering with the spring tides because their place is there. To our understanding, this only highlights that we are dealing with different knowledge systems, with distinct toolkits of explanatory practices. Besides, it is worth noting that essentialist explanations have also been used by natural scientists in the past.

There seems to be a gradient in partial overlaps, ranging from simple ontological convergences, as we find when comparing Gacici in the fishers' taxonomy with *B. aequinoctialis* in the academic taxonomy, to radical alterity, as when we compare Runa's ideas on thinking forests with our Western understanding of mind and cognition. Between these extremes, we can consider cases extending from lumping-splitting in distinct taxonomies to fishers' complex causal explanations that can be interpreted as similar to mechanistic models built by academic scientists.

8 Concluding Remarks

In this paper, we discussed some central ideas in a conceptual framework for intercultural education as dialogue between knowledge systems:

- An understanding of intercultural education as a way of creating conditions for members of different communities to know their own cultures, the culture of others, and be able to cross borders between cultures, in such a manner that two fundamental rights be fulfilled: on the one hand, their right to be equal when difference makes them inferior; on the other, their right to be different when equality makes them lose their identifying characteristics.
- A pluralist pragmatist interpretation of the intercultural attitude, based on the idea that the validity of a cognitive construction should be established through reasoning that starts from or is based on consequences.
- A conception of horizontal dialogue between knowledge systems in science teaching, without losing from sight the goal of understanding scientific ideas while allowing a transition from a "One-World World" to a "world where many worlds fit" in a pluriversal science education.
- An understanding of intercultural dialogue as involving translation as a creative, meaning-making act attentive to controlled equivocation, which can give room to learning from others even in cases of (radical) difference.

– Relational humility, as a virtue that makes us capable of combining a self-ascription of ignorance with other-ascription of important knowledge, such that we participate in epistemic practices leading to active intellectual and social engagement with other knowers, in science education and beyond.
– A partial overlaps framework used in three domains—ontological, epistemological, and axiological—as a manner of considering both approximations (overlaps that provide common bases for collaboration and mutual learning) and differences between knowledge systems (partialities of overlap that foster, on the one hand, reflections nourishing a political philosophy of intercultural relations, and, on the other, ways of learning from difference through intercultural translation).

These ideas have been built not only through philosophical and educational studies, but also through engagement in action research efforts in artisanal fishing communities, which provided us with the opportunity of an immersive experience of collaborative work with local teachers from a school attended by the students from the communities. In this experience, we have been collaborating in building and investigating educational innovations responsive to the theoretical ideas discussed in this paper. There can be no doubt that it is challenging to transpose these ideas to the collaborative work with teachers and to their educational practices, in order to foster intercultural education as dialogue between knowledge systems. The strategy for building this collaborative work, as well as the dialogical processes for a stepwise consideration of the ideas discussed in the paper, is based on the constitution of a community of practice (CoP). To face the challenge of transposing the ideas from the theoretical framework into teacher in-service professional development, and subsequently into teaching practice, we have been relying on an increasing coherence arising in the shared practices of the CoP, in which mutual learning has been successfully taking place.

The teaching innovations developed and investigated in the CoP create space in the classrooms for intercultural education as dialogue between knowledge systems. The intention is to foster educational processes that create opportunities for the students to ascribe value to their origins and the knowledge and practices of the communities of which they are part, while also acquiring tools for critically reading the local and global realities in which they are embedded (Freire, 2002, 2019a, 2019b, 2020). Among these tools, we certainly find school scientific ideas they have an opportunity to learn in the classrooms, but we also need to consider in the CoP how school education can be better adjusted to the communities' ways of living and learning, and how educational processes should not alienate the students from their own culture. It is important that schooling also contributes to the maintenance of the local identity-building processes, while prompting the students to develop their own capacities of crossing cultural borders to understand the culture of others, reaching thus increased possibilities of participating in new social arrangements that can support the communities' struggle towards more self-determination.

We will mention here three examples of teaching innovations developed by the CoP, some scientific ideas addressed, and their relations to elements of the theoretical framework:

– *Cultural tales*, in which the students inquire into stories of their communities and/or families and write them down, with illustrations, connecting school teaching and learning with local memory and narratives. They contribute to students' identity-building processes and reinforce their connections with the communities, preserve the fishers'

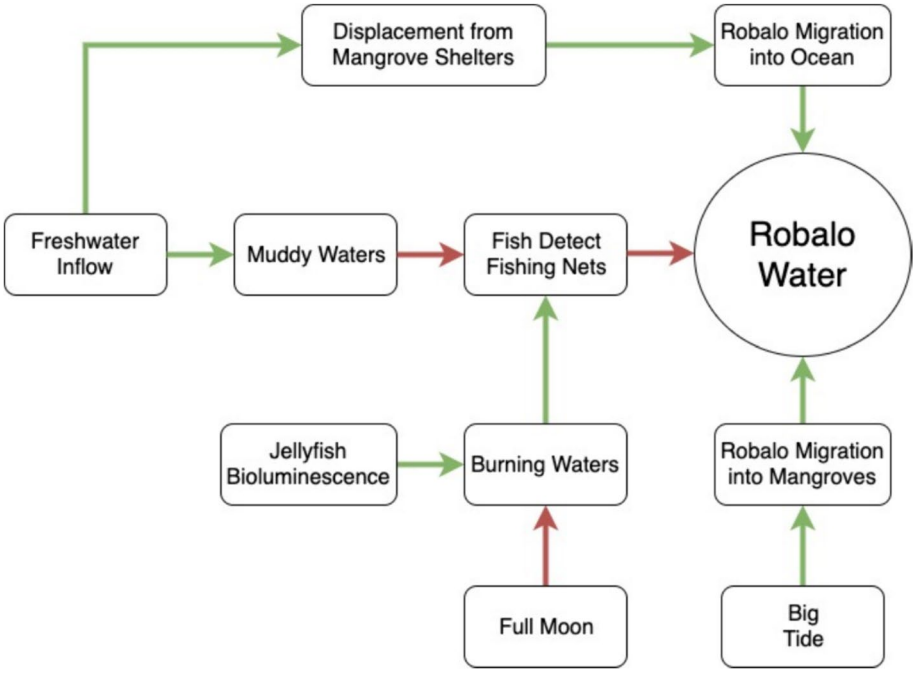

Fig. 2 A mechanistic model built from the articulation of entities and activities involved in the production of the phenomenon "Robalo water" in the estuary where the fishing communities of Siribinha and Poças are situated, according to the fishers' explanations. Green and red arrows indicate positive and negative causal effects, respectively (figure elaborated by the authors)

cultural heritage, and create room for dialogue between local knowledge/practices and scientific school content, for instance, about climate and its relationship with fishing work, environmental conservation and sustainability, knowledge about plants and animals, etc. (for more details, see El-Hani, 2022; Almeida, 2022; Silva, 2022). The partial overlaps approach can play a key role in exploring the relations between local and school knowledge using the cultural tales. The same can be said of the appraisal of the pragmatic situated value of these knowledges, especially considering the communities' and students' needs.

– *Garden of local plants*, engaging teachers and students in research on the local knowledge about plants and their uses, in dialogue with previous studies of our team (Tng et al., 2021), culminating in the construction of a garden with plants used by the communities as food and medicine. This garden will have information boards elaborated by the students, putting botanical school knowledge in dialogue with local plant knowledge, for future generations to use for learning. A methodology of partial overlaps will be used in the classroom for the students to elaborate these information boards, while the situated role of the local plant knowledge in the communities' activities will be discussed, as well as the relevance of school knowledge about plants.
– *Socio-environmental perception through photographs and knowledge production practices*, which asks local students, teachers, fishermen, fisherwomen, and university students to take pictures of the communities and their environments in order to show to others how it is to live there and how their territories are. After that, the teachers work

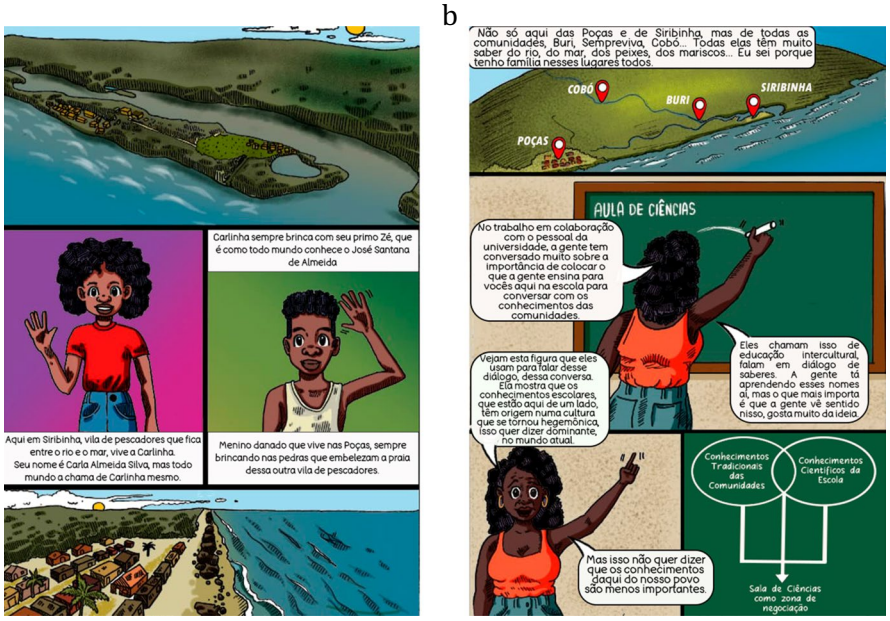

Fig. 3 Excerpts of cartoon used as a way of transposing to the classroom ideas from the theoretical framework for intercultural education as dialogue between knowledge systems. (Translation of the texts in the cartoon excerpts. (a) Narrator: "Carlinha lives here in Siribinha, a fishing village situated between the river and the sea. Her name is Carla Almeida Silva, but everyone calls her Carlinha." Narrator: "Carlinha always plays with his cousin Zé, that's how everyone calls José Santana de Almeida." Narrator: "Lively boy who lives in Poças, always playing in the rocks that embellish the beach in this other fishing village." (b) Teacher: "Not only here in Siribinha and Poças, but in all communities. All of them have a lot of knowledge about the river, the sea, the fish, the shellfish… I know because I have family in all these places". Teacher: "In the collaborative work with the people from the university, we have been talking a lot about the importance of putting what we teach you here in the school in dialogue with the knowledge from the communities." Teacher: "They call this intercultural education, they talk about dialogue between knowledges. We are learning these names, but what is more important is that we think this makes sense, we like the idea a lot." Teacher: "See this image they use to talk about this dialogue, this conversation. It shows that the school knowledge, which is here on one side, originates from a culture that became hegemonic, that is, dominant in the current world." Teacher: "But this does not mean that the knowledge from our people is less important." In the blackboard above, "Science class"; left below, "Traditional knowledge from the communities"; right below, "School science knowledge"; at the bottom, "Science classroom as trading zone.") Script and texts by the first author of this work. Art and digitalization by Jairo Robles-Piñeros (*Universidad Pedagógica Nacional*, Colombia) and Juan Manuel Farietta-Robles (*Universidad Nacional de Colômbia*). **a** First page, presenting the main characters, students of the fishing communities with which we work; **b** p. 5, where the teacher explains the idea of a dialogue between knowledge systems involving the partial overlaps framework and the idea that the classroom can be conceived as a trading zone for school and local knowledge (Robles-Piñeros et al., 2020)

in their classrooms with three indicators of scientific literacy proposed by Sasseron and Carvalho (2008) for primary school: hypothesis raising, justification, and hypothesis testing. The students raise hypotheses on what has been photographed by each of the groups above, then justify these hypotheses, and finally test them by verifying the pictures organized in an exposition. The teaching proposal culminates with a class addressing how these and other knowledge building processes underlie the scientific

contents treated in the textbooks (usually as a "rhetoric of conclusions"; Schwab, 1964) and comparing how academic scientists and fishers raise, justify, and test hypotheses, drawing on our studies on local knowledge construction practices and using the partial overlaps approach. Ideas about the pragmatic value of local and school knowledge can also be considered.

We would also like to highlight a strategy we have been using to bring ideas from the theoretical framework into classroom work, namely, the elaboration of cartoons. For instance, Fig. 3 shows a cartoon in which the partial overlaps approach is explained, attending to the need of didactic transposition, and the fishers' explanation of a regular natural phenomenon in the estuarine environment—namely, that of the cycle of the bivalve Massunim in response to variations in salinity gradient—is put into dialogue with school scientific knowledge. This is an application of outcomes of our work on epistemological overlaps, which was discussed above.

The same cartoon also addresses partialities of overlap in the reproductive periods of different animals as perceived by the fishers and the technical knowledge underlying laws on fisheries closed periods that they need to obey. Finally, it also discusses, from the standpoint of the politics of knowledge, how fishers' descriptions and explanations of phenomena need to be included through bottom-up participatory processes in decision making about laws that affect their ways of being and livelihoods (see above). This political discussion is relevant in view of the epistemic injustice resulting from the fact that causal explanations found in many knowledge systems have been, in the wake of colonization and more recently globalization, deemed inferior or even non-existent by dominant institutions, including fishers' descriptions and explanations of phenomena.

These examples illustrate how research carried out following the theoretical framework presented here nourishes collaborative work in the CoP that results in teaching materials and activities combining science education goals with intercultural education goals. Our expectation is that the present work offers contributions for teachers and researchers aiming at building a more plural, inclusive, empowering, and liberating science education that responds to the challenges facing contemporary intercultural societies. We argued here that such an intercultural science education can be fruitfully based on dialogue between knowledge systems, which involves meaning-making intercultural translation. As a promising outcome of this form of science education, we envision the possibility that at least part of the different subjects and groups that constitute themselves through continuing relations of conflict, negotiation, and exchange in current societies may be relatively less engaged in relations of domination and oppression, and relatively more engaged in dialogical, mutual understanding processes that can lead to new arrangements of culture and power. These arrangements are the horizon of our action research efforts in Indigenous and local communities and in the schools situated in them.

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Declarations

Conflict of Interest The authors declare no competing interests.

References

Adams, F. (2018). Cognition wars. *Studies in History and Philosophy of Science, 68*, 20–30. https://doi.org/10.1016/j.shpsa.2017.11.007

Adler, J. E. (2002). *Belief's own ethics*. The MIT Press.

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. *Development and Change, 26*(3), 413–439. https://doi.org/10.1111/j.1467-7660.1995.tb00560.x

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27*(1), 1–52. https://doi.org/10.1080/03057269608560077

Alcoff, L. M. (2022). Extractivist epistemologies. *Tapuya: Latin American Science, Technology and Society, 5*(1), 2127231. https://doi.org/10.1080/25729861.2022.2127231

Alessa, L., Kliskey, A., Gamble, J., Fidel, M., Beaujean, G., & Gosz, J. (2016). The role of Indigenous science and local knowledge in integrated observing systems: Moving toward adaptive capacity indices and early warning systems. *Sustainability Science, 11*(1), 91–102. https://doi.org/10.1007/s11625-015-0295-7

Almeida, M. W. B. (2013). Caipora e outros conflitos ontológicos. *Revista de Antropologia da UFSCar, 5*(1), 7–28. https://doi.org/10.52426/rau.v5i1.85

Almeida, R. O. (2022). Saberes ancestrais e formação de professores de biologia: aproximações entre história ambiental e narrativas locais na proteção do patrimônio biocultural. *Revista Bio-grafía. Escritos sobre la Biología y su enseñanza*, *número Extraordinario*, 3308–3321.

Aman, R. (2018). *Decolonising intercultural education: Colonial differences, the geopolitics of knowledge, and inter-epistemic dialogue*. Routledge.

Anderson, E. N. (1996). *Ecologies of the heart: Emotion, belief, and the environment*. Oxford University Press.

Anderson, E. (2012). Epistemic justice as a virtue of social institutions. *Social Epistemology, 26*(2), 163–173. https://doi.org/10.1080/02691728.2011.652211

Athayde, S., Silva-Lugo, J., Schmink, M., & Heckenberger, M. (2017). The same, but different: Indigenous knowledge retention, erosion, and innovation in the Brazilian Amazon. *Human Ecology, 45*, 533–544. https://doi.org/10.1007/s10745-017-9919-0

Bakhtin, M. M. (1981). *The dialogic imagination: Four essays by M. M. Bakhtin.* In M. Holquist, C. Emerson, & M. Holquist (Eds.) Trans. University of Texas Press.
Banks, J. A. (1999). *An introduction to multicultural education* (4th ed.). Pearson.
Baptista, G. C., & El-Hani, C. N. (2009). The contribution of ethnobiology to the construction of a dialogue between ways of knowing: A case study in a Brazilian public high school. *Science & Education, 18*(3–4), 503–520. https://doi.org/10.1007/s11191-008-9173-3
Baptista, G. C. S. (2018). Tables of contextual cognition: A proposal for intercultural research in science education. *Cultural Studies of Science Education, 13*, 845–863. https://doi.org/10.1007/s11422-017-9807-3
Barbosa, L. P. (2022). Onto-epistemic paradigm of the countryside and social theory: What do popular movements of Latin America and the Caribbean teach us? *Educational Studies, 58*(5), 620–640. https://doi.org/10.1080/00131946.2022.2132392
Begossi, A. (2008). Local knowledge and training towards management. *Environment, Development and Sustainability, 10*(5), 591–603. https://doi.org/10.1007/s10668-008-9150-7
Berlin, B. (1992). *Ethnobiological classification*. Princeton University Press.
Berlin, B., Shilts Boster, J., & O'Neill, J. P. (1981). The perceptual bases of ethnobiological classification: Evidence from Aguaruna Jivaro ornithology. *Journal of Ethnobiology, 1*(1), 95–108.
Bhabha, H. K. (2015). Foreword. In P. Werbner & T. Modood (Eds.), *Debating cultural hybridity: Multicultural identities and the politics of anti-racism*. Zed Books.
BirdLife International (2023) Species factsheet: *Buteogallus aequinoctialis*. Retrieved August 24, 2023, from http://datazone.birdlife.org/species/factsheet/rufous-crab-hawk-buteogallus-aequinoctialis.
Boghossian, P. A. (2006). *Fear of knowledge: Against relativism and constructivism*. Oxford University Press.
Bollettin, P., Ludwig, D., & El-Hani, C. (2023). Challenges of symmetrical dialogue: Reflections on collaborative research in Northeast Brazil. *Ethnobiology Letters, 14*(2), 47–55. https://doi.org/10.14237/ebl.14.2.2023.1836
Brayboy, B. M. J., & Castagno, A. E. (2008). How might Native science inform "informal science learning"? *Cultural Studies of Science Education, 3*, 731–750. https://doi.org/10.1007/s11422-008-9125-x
Brum, E. (2021). *Banzeiro òkòtó*. Companhia das Letras.
Cámara-Leret, R., & Bascompte, J. (2021). Language extinction triggers the loss of unique medicinal knowledge. *Proceedings of the National Academy of Sciences of the United States of America, 118*(24), e2103683118. https://doi.org/10.1073/pnas.2103683118
Campos, M. D. (1991). A arte de sulear-se. In T. C. Scheiner (Ed.), *Interação museu-comunidade pela educação ambiental* (pp. 59–61). TACNET Cultural.
Candau, V. M. (2006). Diálogos entre diferença e educação. In V. M. Candau (Ed.), *Educação intercultural e cotidiano escolar* (pp. 121–139). 7 Letras.
Canen, A. (1997). Formação de professores e diversidade cultural. In V. M. Candau (Org.), *Magistério: Construção cotidiana* (pp. 205–236). Vozes.
Chilisa, B. (2012). *Indigenous research methodologies*. Sage.
Cobern, W. W. (1996). Worldview theory and conceptual change in science education. *Science Education, 80*, 579–610. https://doi.org/10.1002/(SICI)1098-237X(199609)80:53.0.CO;2-8
Cobern, W. W., & Aikenhead, G. S. (1998). Cultural aspects of learning science. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 39–52). Kluwer Academic Publishers.
Cornell, S., Berkhout, F., Tuinstra, W., Tàbara, J. D., Jäger, J., Chabay, I., de Wit, B., Langlais, R., Mills, D., Moll, P., et al. (2013). Opening up knowledge systems for better responses to global environmental change. *Environmental Science & Policy, 28*, 60–70. https://doi.org/10.1016/j.envsci.2012.11.008
Costa, V. B. (1995). When science is "another world": Relationships between worlds of family, friends, school, and science. *Science Education, 79*(3), 313–333. https://doi.org/10.1002/sce.3730790306
Cruz, J. D. (2018). Los estudios de paz latinoamericanos en la encrucijada. Producir o reproducir, una mirada desde las epistemologías del Sur. *Revista CoPaLa, 5*, 9–21. www.redalyc.org/pdf/6681/668170992002.pdf
Dalmiya, V. (2007). Unraveling leadership: 'Relational humility' and the search for ignorance. In P. D. Hershock, M. Mason, & J. N. Hawkins (Eds.), *Changing education: Leadership, innovation and development in a globalizing Asia Pacific* (pp. 297–322). Comparative Education Research Centre.
Davidson, D. (1984). *Inquiries into truth & interpretation*. Clarendon Press.
Davidson-Hunt, I. J., Turner, K. L., Mead, A. T. P., Cabrera-Lopez, J., Bolton, R., Idrobo, C. J., Miretski, I., Morrison, A., & Robson, J. P. (2012). Biocultural design: A new conceptual framework for sustainable development in rural indigenous and local communities. *SAPIENS. Surveys and*

Perspectives Integrating Environment and Society, 5(2), 1–13. https://journals.openedition.org/sapiens/1382.

Diegues, A. C. (1999). A sócio-antropologia das comunidades de pescadores marítimos no Brasil. *Etnográfica, III*(2), 361–375.

Dotson, K. (2014). Conceptualizing epistemic oppression. *Social Epistemology, 28*(2), 115–138. https://doi.org/10.1080/02691728.2013.782585

Dwivedi, R. (2001). Environmental movements in the global south: Issues of livelihood and beyond. *International Sociology, 16*(1), 11–31. https://doi.org/10.1177/0268580901016001003

Ellen, R. (2006). *The categorical impulse: Essays in the anthropology of classifying behaviour*. Berghahn Books.

Ellen, R. (2016). Is there a role for ontologies in understanding plant knowledge systems? *Journal of Ethnobiology, 36*(1), 10–28. https://doi.org/10.2993/0278-0771-36.1.10

El-Hani, C. N. (2022). Bases teórico-filosóficas para o design de educação intercultural como diálogo de saberes. *Investigações em Ensino de Ciências, 27*(1), 1–38. https://doi.org/10.22600/1518-8795.ienci2022v27n1p01

El-Hani, C. N., & Almeida, R. O. (2022). Spaces of encounter and misencounter between researchers and local people in interdisciplinary and transdisciplinary studies in fishing villages. In M. Guilherme (Ed.), *A framework for critical transnational research: Advancing plurilingual, intercultural, and inter-epistemic collaboration in the academy* (pp. 101–122). Routledge.

El-Hani, C. N., & Bandeira, F. P. S. F. (2008). Valuing indigenous knowledge: To call it "science" will not help. *Cultural Studies of Science Education, 3*(3), 751–779. https://doi.org/10.1007/s11422-008-9129-6

El-Hani, C. N., & Greca, I. M. (2013). ComPratica: A virtual community of practice for promoting biology teachers' professional development in Brazil. *Research in Science Education, 43*, 1327–1359. https://doi.org/10.1007/s11165-012-9306-1

El-Hani, C. N., & Mortimer, E. F. (2007a). Multicultural education pragmatism and the goals of science teaching. *Cultural Studies of Science Education, 2*(3), 657–702. https://doi.org/10.1007/s11422-007-9064-y

El-Hani, C. N., & Mortimer, E. F. (2007b). Understanding typically yields belief: A neglected point in Hoffmann's reaction to our idea of 'culturally-sensitive science education'. *Cultural Studies of Science Education, 2*(3), 695–702. https://doi.org/10.1007/s11422-007-9064-y

El-Hani, C. N., & Reis, C. R. M. (2021). Research strategies and value outlooks in scientific practices: For an organicist thinking and a pluralist methodology in the biological sciences. *Philosophy World Democracy.* Available in: https://www.philosophy-world-democracy.org/articles-1/research-strategies-and-value-outlooks-in-scientific-practices. Accessed 1 May 2024

El-Hani, C. N., & Pihlström, S. (2002). Emergence theories and pragmatic realism. *Essays in Philosophy, 3*(2), 143–176. https://doi.org/10.5840/eip2002325

El-Hani, C. N., Poliseli, L., & Ludwig, D. (2022). Beyond the divide between Indigenous and academic knowledge: Causal and mechanistic explanations in a Brazilian fishing community. *Studies in History and Philosophy of Science, 91*, 296–306. https://doi.org/10.1016/j.shpsa.2021.11.001

Erduran, S., & Dagher, Z. R. (2014). *Reconceptualizing the nature of science for science education*. Springer.

Escobar, A. (2016). Sentipensar con la tierra: las luchas territoriales y la dimensión ontológica de las epistemologías del Sur. *Revista de Antropología Iberoamericana, 11*(1), 11–32. https://doi.org/10.11156/aibr.110102

Escobar, A. (2018). *Designs for the pluriverse: Radical interdependence, autonomy, and the making of worlds*. Duke University Press.

Evnine, S. J. (2001). Learning from one's mistakes: Epistemic modesty and the nature of belief. *Pacific Philosophical Quarterly, 82*(2), 157–177. https://doi.org/10.1111/1468-0114.00123

Farrell, K. N. (2020). Untrol: Post-truth and the new normal of post-normal science. *Social Epistemology, 34*(4), 330–345. https://doi.org/10.1080/02691728.2019.1706117

Fernández-Llamazares, A., Lepofsky, D., Lertzman, K., Armstrong, C. G., Brondizio, E. S., et al. (2021). Scientists' warning to humanity on threats to Indigenous and local knowledge systems. *Journal of Ethnobiology, 41*(2), 144–169. https://doi.org/10.2993/0278-0771-41.2.144

Feyerabend, P. K. (1962). Explanation, reduction and empiricism. In H. Feigl & G. Maxwell (Eds.), *Scientific explanation, space, and time (Minnesota Studies in the Philosophy of Science, Volume III)* (pp. 28–97). University of Minneapolis Press.

Feyerabend, P. K. (1975). *Against method. Outline of an anarchistic theory of knowledge* (1st ed.). New Left Books.

Freire, P. (1992). *Pedagogia da esperança: Um reencontro com a pedagogia do oprimido* (4th ed.). Paz e Terra.
Freire, P. (2002). *Pedagogia da autonomia: Saberes necessários à prática educativa* (25th ed.). Paz e Terra.
Freire, P. (2019a). *Pedagogia do oprimido*. Paz e Terra.
Freire, P. (2019b). *Educação como prática da liberdade* (50th ed.). Paz e Terra.
Freire, P. (2020). *Educação e mudança* (45th ed.). Paz e Terra.
Fricker, M. (2007). *Epistemic injustice: Power and the ethics of knowing*. Oxford University Press.
Fuller, S. (2018). *Post-truth: Knowledge as a power game*. Anthem Press.
Fúnez-Flores, J. I. (2023). Toward decolonial globalisation studies. *Globalisation, Societies and Education, 21*(2), 166–186. https://doi.org/10.1080/14767724.2022.2048796
García Canclini, N. (2004). *Diferentes, desiguales y desconectados*. *Mapas de la interculturalidad*. Gedisa.
Gavin, M. C., McCarter, J., Mead, A., Berkes, F., Stepp, J. R., Peterson, D., & Tang, R. (2015). Defining biocultural approaches to conservation. *Trends in Ecology & Evolution, 30*(3), 140–145. https://doi.org/10.1016/j.tree.2014.12.005
Geertz, C. (1973). *The interpretation of cultures*. Basic Books.
Gilbert, J. K., & Watts, D. M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education, 10*(1), 61–98. https://doi.org/10.1080/03057268308559905
Grupioni, L. D. B. (2013). Quando a Antropologia se defronta com a Educação: Formação de professores índios no Brasil. *Pro-Posições, 24*(2), 69–80. https://doi.org/10.1590/S0103-73072013000200006
Hall, S. (2006). *A identidade cultural na pós-modernidade* (11th ed.). DP&A.
Hoffmann, M. H. G. (2007). Learning without belief-change? *Cultural Studies of Science Education, 2*, 688–694. https://doi.org/10.1007/s11422-007-9064-y
Holbraad, M., & Pedersen, M. A. (2017). *The ontological turn*. Cambridge University Press.
Hoyningen-Huene, P. (1993). *Reconstructing scientific revolutions: Thomas S. Kuhn's philosophy of science*. The University of Chicago Press.
Hunn, E. (2014). To know them is to love them. *Ethnobiology Letters*, *5*, 146–150. https://doi.org/10.14237/ebl.5.2014.297
Huntington, H. P. (2000). Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications, 10*(5), 1270–1274. https://doi.org/10.1890/1051-0761(2000)010[1270:UTEKIS]2.0.CO;2
Hutchison, A. (2014). The Whanganui River as a legal person. *Alternative Law Journal, 39*(3), 179–182. https://doi.org/10.1177/1037969X1403900309
Illari, P. M., & Williamson, J. (2012). What is a mechanism? Thinking about mechanisms across the sciences. *European Journal for Philosophy of Science, 2*(1), 119–135. https://doi.org/10.1007/s13194-011-0038-2
Ivenicki, A. (2018). Multiculturalismo e formação de professores: Dimensões, possibilidades e desafios na contemporaneidade. *Ensaio: Avaliação e Políticas Públicas em Educação, 26*(100), 1151–1167. https://doi.org/10.1590/S0104-40362018002601186
Johnson, J. T., Howitt, R., Cajete, G., Berkes, F., Louis, R. P., & Kliskey, A. (2016). Weaving Indigenous and sustainability sciences to diversify our methods. *Sustainability Science, 11*(1), 1–11. https://doi.org/10.1007/s11625-015-0349-x
Kamii, C., & DeVries, R. (1993). *Physical knowledge in preschool education: Implications of Piaget's theory*. Teachers College Press.
Kato, D. S., Galamba, A., & Monteiro, B. A. P. (2023). Decolonial scientific education to combat 'science for domination.' *Cultural Studies of Science Education, 18*, 217–235. https://doi.org/10.1007/s11422-023-10165-4
Kawagley, A. (1990). Yup'ik ways of knowing. *Canadian Journal of Native Education, 17*(2), 5–17.
Khalidi, M. A. (2013). *Natural categories and human kinds*. Cambridge University Press.
Kimmerer, R. W. (2012). Searching for synergy: Integrating traditional and scientific ecological knowledge in environmental science education. *Journal of Environmental Studies and Sciences, 2*(4), 317–323. https://doi.org/10.1007/s13412-012-0091-y
Koskinen, I., & Ludwig, D. (2022). Philosophy or philosophies? Epistemology or epistemologies? In D. Ludwig, I. Koskinen, Z. Mncube, L. Poliseli, & L. Reyes-Galindo (Eds.), *Global epistemologies and philosophies of science* (pp. 15–25). Routledge.
Kohn, E. (2013). *How forests think: Toward an anthropology beyond the human*. University of California Press.
Kovach, M. (2009). *Indigenous methodologies: Characteristics, conversations, and contexts*. University of Toronto Press.

Kuhn, T. S. ([1962]1996). *The structure of scientific revolutions*. The University of Chicago Press.
Lacey, H. (2014). On the co-unfolding of scientific knowledge and viable values. In P. Schroeder-Heister, G. Heinzmann, W. Hodges, & P. E. Bour (Eds.), *Logic, methodology and philosophy of science. Proceedings of the Fourteenth International Congress (Nancy)* (pp. 269–284). College Publications.
Lacey, H. (2016). Science, respect for nature, and human well-being: Democratic values and the responsibilities of scientists today. *Foundations of Science, 21*(1), 51–67. https://doi.org/10.1007/s10699-014-9376-9
Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465–491. https://doi.org/10.3102/00028312032003465
Lansing, J. S. (1991). *Priests and programmers: Technologies of power in the engineered landscape of Bali*. Princeton University Press.
Lansing, J. S., & Kremer, J. N. (1993). Emergent properties of Balinese water temple networks: Coadaptation on a rugged fitness landscape. *American Anthropologist, 95*(1), 97–114. https://doi.org/10.1525/aa.1993.95.1.02a00050
Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
Law, J. (2015). What's wrong with a one-world world? *Distinktion: Journal of Social Theory, 16*(1), 126–139. https://doi.org/10.1080/1600910X.2015.1020066
Lee, O., & Luykx, A. (2006). *Science education and student diversity: Synthesis and research agenda*. Cambridge University Press.
Leff, E. (2003). Racionalidad ambiental y dialogo de saberes: Sentidos y senderos de un futuro sustentable. In C. Raynault, M. Zanoni, & P. C. Lana (Orgs.), *Desenvolvimento e meio ambiente* (pp. 13–40). Editora UFPR.
Levander, C., & Mignolo, W. (2011). Introduction: The global south and world dis/order. *The Global South, 5*(1), 1–11. https://doi.org/10.2979/globalsouth.5.1.1
Lien, M. E., & Pálsson, G. (2019). Ethnography beyond the human: The 'other-than-human' in ethnographic work. *Ethnos, 86*(1), 1–20. https://doi.org/10.1080/00141844.2019.1628796
Lima, A. C. S., & Barroso-Hoffmann, M. (Orgs.) (2004). *Desafios para uma educação superior para os povos indígenas no Brasil: Políticas públicas de ação afirmativa e direitos culturais diferenciados*. LACED – Departamento de Antropologia/Museu Nacional-UFRJ.
Longino, H. (1990). *Science as social knowledge: Values and objectivity in scientific inquiry*. Princeton University Press.
Ludwig, D. (2016). Overlapping ontologies and Indigenous knowledge. From integration to ontological self-determination. *Studies in History and Philosophy of Science Part A, 59*, 36–45. https://doi.org/10.1016/j.shpsa.2016.06.002
Ludwig, D. (2018a). Revamping the metaphysics of ethnobiological classification. *Current Anthropology, 59*(4), 415–438. https://doi.org/10.1086/698958
Ludwig, D. (2018b). Letting go of 'natural kind'. Towards a multidimensional framework of non-arbitrary classification. *Philosophy of Science, 85*, 31–52. https://doi.org/10.1086/694835
Ludwig, D., & El-Hani, C. N. (2020). Philosophy of Ethnobiology: Understanding knowledge integration and its limitations. *Journal of Ethnobiology, 40*(1), 3–20. https://doi.org/10.2993/0278-0771-40.1.3
Ludwig, D., & Poliseli, L. (2018). Relating traditional and academic ecological knowledge: mechanistic and holistic epistemologies across cultures. *Biology & Philosophy, 33*(5–6), 43. https://doi.org/10.1007/s10539-018-9655-x
Ludwig, D., El-Hani, C. N., Gatti, F., Kendig, C., Kramm, M., Neco, L., Delgado, A. N., Renck, V., Ressiore C. A., Galindo, L. R., Rickard, T. L., De La Rosa, G., Turska, J., Vergara-Silva, F., & Wilson, R. A. (2023). Transdisciplinary philosophy of science: Meeting the challenge of Indigenous expertise. *Philosophy of Science*. https://doi.org/10.1017/psa.2023.127
Macionis, J. J. (2010). *Sociology* (13th ed.). Pearson Education.
Margolis, J. (1991). *The truth of relativism*. Blackwell.
Marlor, C. (2010). Bureaucracy, democracy and exclusion: Why Indigenous knowledge holders have a hard time being taken seriously. *Qualitative Sociology, 33*(4), 513–531. https://doi.org/10.1007/s11133-010-9168-7
Martin, K. (1995). The foundational values of cultural learning: The Akhkwasahsne science and math pilot project. *Winds of Change, 10*, 50–55.
McIntyre, L. (2018). *Post-truth*. The MIT Press.
Messeder Neto, H. S., & Rosa, J. M. (2022). A dialética consciente/não-consciente na concepção de mundo: Implicações teóricas, metodológicas e práticas para o ensino de ciências da natureza na perspectiva

histórico-crítica. *Ensaio: Pesquisa em Educação em Ciências, 24*, e400097. https://doi.org/10.1590/1983-21172022240116
Meyer, M. (1908). The exact number of pragmatisms. *The Journal of Philosophy, Psychology and Scientific Methods, 5*(12), 321–326. https://doi.org/10.2307/2011805
Mitchell, S. D. (2003). *Biological complexity and integrative pluralism*. Cambridge University Press.
Mohanty, C. T. (2003). *Feminism without borders: Decolonizing theory, practicing solidarity*. Duke University Press.
Molina-Andrade, A. (2015). Línea de investigación enseñanza de las ciencias, contexto y diversidad cultural: estado de desarrollo. *Revista EDUCyT*, *10*, 76–81. http://hdl.handle.net/10893/8715
Mortimer, E. F., & El-Hani, C. N. (Eds.) (2014). *Conceptual profiles: A theory of teaching and learning scientific concepts*. Springer.
Mungwini, P. (2017). Pan-africanism and epistemologies of the South. *Theoria: A Journal of Social and Political Theory*, *64*(153): 165–186. https://doi.org/10.3167/th.2017.6415310
Musiello-Fernandes, J., Zappes, C. A., & Hostim-Silva, M. (2017). Small-scale shrimp fisheries on the Brazilian coast. *Ocean & Coastal Management, 148*, 89–96. https://doi.org/10.1016/j.ocecoaman.2017.07.018
Nadasdy, P. (1999). The politics of TEK: Power and the 'integration' of knowledge. *Arctic Anthropology*, *36*(1/2), 1–18. https://www.jstor.org/stable/40316502
Nadasdy, P. (2003). *Hunters and bureaucrats: Power, knowledge, and aboriginal-state relations in the Southwest Yukon*. UBC Press.
Nadasdy, P. (2005). The anti-politics of TEK: The institutionalization of co-management discourse and practice. *Anthropologica*, *47*(2), 215–232. https://www.jstor.org/stable/25606237
Nunes, J. A. (2021). Epistemologies of the South meet the insurrectionist turn in pragmatism: Steps towards a dialogue. *Pragmatism Today*, *12*(1), 19–40. https://www.pragmatismtoday.eu/summer2021/Epistemologies-of-the-South-Meet-the-Insurrectionist-Turn-in-Pragmatism-Steps-towards-a-dialogue-Joao-Arriscado-Nunes.pdf
Oberheim, E., & Hoyningen-Huene, P. (2018). The incommensurability of scientific theories. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy* (Fall 2018 Edition). https://plato.stanford.edu/archives/fall2018/entries/incommensurability/
Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*(5), 583–593. https://doi.org/10.1002/sce.3730790507
Ott, C. F. (1944). Os elementos culturais da pescaria baiana. *Boletim Do Museu Nacional, 4*, 1–67.
Peirce, C. S. (1878). How to make our ideas clear. *Popular Science Monthly, 12*, 286–302.
Peirce, C. S. (1931–1935). *The collected papers of Charles Sanders Peirce*. Intelex Corporation.
Pejaner, K. J. B., & Mistades, V. M. (2020). Culturally relevant science teaching: A case study of physics teaching practices of the "Obo Monuvu" tribe. *Science Education International, 31*(2), 185–194. https://doi.org/10.33828/sei.v31.i2.8
Pérez-Ruiz, M. L., & Argueta Villamar, A. (2011). Saberes indígenas y dialogo intercultural. *Cultura y Representaciones Sociales, 5*(10), 31–56.
Peroza, J., Silva, C. P., & Akkari, A. (2013). Paulo Freire e a diversidade cultural: Um humanismo político-pedagógico para a transculturalidade na educação. *Revista Reflexão e Ação, 21*(2), 461–481. https://doi.org/10.17058/rea.v21i2.3208
Pihlström, S. (1996). Structuring the world: The issue of realism and the nature of ontological problems in classical and contemporary pragmatism. *Acta Philosophica Fennica*, 59. The Philosophical Society of Finland.
Posey, D. A., with contributions by Dutfield, G., Plenderleith, K., da Costa e Silva, E., & Argumedo, A. (1996). *Traditional resource rights: International instruments for protection and compensation for Indigenous peoples and local communities*. IUCN.
Pratt, M. L. (2008). *Imperial eyes: Travel writing and transculturation* (2nd ed.). Routledge.
Pratt, S. L. (2002). *Native pragmatism: Rethinking the roots of American philosophy*. Indiana University Press.
Putnam, H. (1981). *Reason, truth and history*. Cambridge University Press.
Putnam, H. (1990). *Realism with a human face* (J. Conant, Ed.). Harvard University Press.
Putnam, H. (1994) *Words and Life* (J. Conant, Ed.). Harvard University Press.
Quine, W. V. O. (1960). *Word and object*. The MIT Press.
Quine, W. V. O. (1969). *Ontological relativity and other essays*. Columbia University Press.
Rathwell, K. J., Armitage, D., & Berkes, F. (2015). Bridging knowledge systems to enhance governance of the environmental commons: A typology of settings. *International Journal of the Commons*, *9*(2), 851–880. https://doi.org/10.18352/ijc.584

Renck, V., Ludwig, D., Bollettin, P., & El-Hani, C. N. (2022). Exploring partial overlaps between knowledge systems in a Brazilian fishing *community. Human Ecology, 50*, 633–649. https://doi.org/10.1007/s10745-022-00335-3

Renck, V., Ludwig, D., Bollettin, P., Reis-Filho, J. A., Poliseli, L., & El-Hani, C. N. (2023a). Taking fishers' knowledge and their implications to fisheries policy seriously. *Ecology & Society, 28*(2), 7. https://doi.org/10.5751/ES-14104-280207

Renck V., Ludwig, D., Santos, I. J., Santos, V. C., Conceição, F. A., Araújo, N. A., Santos, C. C., Oliveira, V. J., Bollettin, P., Reis-Filho, J. A., Poliseli, L., & El-Hani. C. N. (2023b). Conhecimento Pesqueiro e o Defeso: preenchendo uma lacuna necessária. *Ethnobiology and Conservation, 12*, 04. https://doi.org/10.15451/ec2023-02-12.04-1-8

Rescher, N. (1995). Pragmatism. In T. Honderich (Ed.), *The Oxford companion to philosophy* (pp. 710–713). Oxford University Press.

Rist, S., & Dahdouh-Guebas, F. (2006). Ethnosciences – A step towards the integration of scientific and indigenous forms of knowledge in the management of natural resources for the future. *Environment, Development and Sustainability, 8*(4), 467–493. https://doi.org/10.1007/s10668-006-9050-7

Robles-Piñeros, J., Ludwig, D., Baptista, G. C. S., & Molina-Andrade, A. (2020). Intercultural science education as a trading zone between traditional and academic knowledge. *Studies in History and Philosophy of Biological & Biomedical Sciences, 84*, 101337. https://doi.org/10.1016/j.shpsc.2020.101337

Rorty, R. (1991). *Objectivity, relativism, and truth: Philosophical papers* (Vol. 1). Cambridge University Press.

Salmon, G. (2017). On ontological delegation. The birth of neoclassical anthropology. In P. Charbonnier, G. Salmon, & P. Skafish (Eds.), *Comparative metaphysics: Ontology after anthropology* (pp. 41–60). Rowman & Littlefield.

Santos, B. S. (1997). Por uma concepção multicultural de direitos humanos. *Revista Crítica De Ciências Sociais, 48*, 11–32. https://doi.org/10.1590/s0102-64451997000100007

Santos, B. S. (2001). *As tensões da modernidade*. In Fórum Social Mundial, Biblioteca das Alternativas. Retrieved January 8, 2023, from http://www.susepe.rs.gov.br/upload/1325792284_As%20tens%C3%B5es%20da%20Modernidade%20-%20Boaventura%20de%20Sousa%20Santos.pdf

Santos, B. S. (2007). *Renovar a teoria crítica e reinventar a emancipação social*. Boitempo.

Santos, B. S. (2010). Para além do pensamento abissal: Das linhas globais a uma ecologia de saberes. In B. S. Santos, & M. P. Meneses (Orgs.), *Epistemologias do Sul* (2nd ed., pp. 23–71). Almedina/CES.

Santos, B. S. (2016). *Epistemologies of the South: Justice against epistemicide*. Routledge.

Santos, B. S. (2018). *The end of the cognitive empire: The coming of age of Epistemologies of the South*. Duke University Press.

Santos, B. S., & Meneses, M. P. (2010a). Prefácio. In B. Sousa Santos, & M. P. Meneses (Orgs.), *Epistemologias do Sul* (2nd ed., pp. 7–8). Almedina/CES.

Santos, B. S., & Meneses, M. P. (2010b). Introdução. In B. Sousa Santos, & M. P. Meneses (Orgs.), *Epistemologias do Sul* (2nd ed., pp. 9–19). Almedina/CES.

Sasseron, L. H., & Carvalho, A. M. P. (2008). Almejando a alfabetização científica no ensino fundamental: A proposição e a procura de indicadores do processo. *Investigações em Ensino de Ciências, 13*(3), 333–352. https://ienci.if.ufrgs.br/index.php/ienci/article/view/445

Schwab, J. J. (1964). The structure of the natural sciences. In G. W. Ford, & L. Pugno (Eds.), *The structure of knowledge and the curriculum*. Rand-McNally.

Scott, P., Mortimer, E. F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90*(4), 605–631. https://doi.org/10.1002/sce.20131

Segundo-Ortin, M., & Calvo, P. (2019). Are plants cognitive? A reply to Adams. *Studies in History and Philosophy of Science, 73*, 64–71. https://doi.org/10.1016/j.shpsa.2018.12.001

Serpa, A. (2006). *Cultura escolar em movimento: Diálogos possíveis*. Universidade Federal Fluminense (Master's dissertation). Retrieved August 11, 2023, from https://app.uff.br/riuff/bitstream/handle/1/17062/Dissert-Andrea%20Serpa.pdf?sequence=1

Silva, A. A. (2022). *Educação intercultural e diálogo entre diferentes saberes: Desafios e possibilidades no ensino de ciências da escola básica*. Universidade Federal da Bahia e Universidade Estadual de Feira de Santana (Master's dissertation). Retrieved December 30, 2023, from https://repositorio.ufba.br/handle/ri/35562

Slater, M. H. (2015). Natural kindness. *The British Journal for the Philosophy of Science, 66*(2), 375–411. https://doi.org/10.1093/bjps/axt033

Smith, M. U., & Siegel, H. (2004). Knowing, believing, and understanding: What goals for science education? *Science & Education, 13*, 553–582. https://doi.org/10.1023/B:SCED.0000042848.14208.bf

Snively, G., & Corsiglia, J. (2001). Rediscovering indigenous science: Implications for science education. *Science Education, 85*(1), 6–34. https://doi.org/10.1002/1098-237X(200101)85:1%3c6::AID-SCE3%3e3.0.CO;2-R

Theunissen, B. (2018). The transformation of the Dutch farm horse into a riding horse: Livestock breeding, science, and "modernization", 1960s–1980s. *Agricultural History, 92*(1), 24–53. https://doi.org/10.3098/ah.2018.092.1.024

Tng, D. Y. P., Apgaua, D. M. G., Lisboa, M. S., & El-Hani, C. N. (2021). Gender differences in plant use knowledge within a traditional fishing community in northeastern Brazil. *Ethnobotany Research and Applications, 21*, 1–36. https://doi.org/10.32859/era.21.12.1-36

Trewavas, A. (2003). Aspects of plant intelligence. *Annals of Botany, 92*(1), 1–20. https://doi.org/10.1093/aob/mcg101

Tsing, A. L. (2005). *Friction: An ethnography of global connection*. Princeton University Press.

Valderrama-Pérez, D. F., Molina-Andrade, A., & El-Hani, C. N. (2015). Dialogue between scientific and traditional knowledge in the science classroom: Development study of a teaching sequence in a school in Taganga (Magdalena, Colombia). *Procedia: Social and Behavioral Sciences, 167*, 217–222. https://doi.org/10.1016/j.sbspro.2014.12.665

Valderrama-Pérez, D. F., El-Hani, C. N., & Molina, A. (2020). Diálogos entre distintas formas de conocimiento en el aula de ciencias: Reflexiones teóricas y metodológicas. In A. Molina (Ed.), *Investigación y formación de profesores de ciencias: Diálogos de perspectivas latinoamericanas* (pp. 191–220). Editorial Universidad Distrital Francisco José de Caldas.

van Kerkhoff, L., & Szlezák, N. A. (2016). The role of innovative global institutions in linking knowledge and action. *Proceedings of the National Academy of Sciences of the United States of America, 113*(17), 4603–4608. https://doi.org/10.1073/pnas.0900541107

Vasques, R. O. R., & Couto, E. D. C. G. (2011). Percepção dos pescadores quanto ao estabelecimento do período de defeso da pesca de arrasto para a região de Ilhéus (Bahia, Brasil). *Revista de Gestão Costeira Integrada, 11*(4), 479–485. https://www.redalyc.org/articulo.oa?id=388340135010.

Viveiros de Castro, E. (2004). Perspectival anthropology and the method of controlled equivocation. *Tipití: Journal of the Society for the Anthropology of Lowland South America, 2*(1), 3–22. https://digitalcommons.trinity.edu/tipiti/vol2/iss1/1

Viveiros de Castro, E. (2015). Who is afraid of the ontological wolf? Some comments on an ongoing anthropological debate. *The Cambridge Journal of Anthropology, 33*(1), 2–17. https://doi.org/10.3167/ca.2015.330102

Wanderer, J. (2012). Addressing testimonial injustice: Being ignored and being rejected. *The Philosophical Quarterly, 62*(246), 148–169. https://doi.org/10.1111/j.1467-9213.2011.712.x

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Harvester Wheatsheaf.

Whyte, K. P., Brewer, J. P., II., & Johnson, J. T. (2016). Weaving Indigenous science, protocols and sustainability science. *Sustainability Science, 11*(1), 25–32. https://doi.org/10.1007/s11625-015-0296-6

Wilson, S. (2008). *Research is ceremony: Indigenous research methods*. Fernwood.

Wisker, G., Robinson, G., & Shacham, M. (2007). Postgraduate research success: Communities of practice involving cohorts, guardian supervisors and online communities. *Innovations in Education and Teaching International, 44*(3), 301–320. https://doi.org/10.1080/14703290701486720

Wolton, D. (2004). *La otra mundialización: Los desafios de la cohabitación cultural global*. Gedisa.

Wolverton, S., Nolan, J. M., & Ahmed, W. (2014). Ethnobiology, political ecology, and conservation. *Journal of Ethnobiology, 34*(2), 125–153. https://doi.org/10.2993/0278-0771-34.2.125

Wolverton, S., Figueroa, R. M., & Swentzell, P. (2016). Archaeology, heritage, and moral terrains: Two cases from the Mesa Verde Region. *Ethnobiology Letters, 7*(2), 23–31. https://doi.org/10.14237/ebl.7.2.2016.695