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FORUM

Valuing indigenous knowledge: to call it "science" will not help

Charbel Niño El-Hani · Fábio Pedro Souza de Ferreira Bandeira

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Abstract In this commentary on Brayboy and Castagno's paper, published in this volume, we discuss, on the one hand, many points of agreement between their proposal of culturally responsive schooling for indigenous youth and El-Hani and Mortimer's proposal of culturally-sensitive science education. On the other hand, we focus on a key disagreement, not only with Brayboy and Castagno, but with a whole body of literature on multicultural, postcolonialist, postmodernist education. The main point of disagreement lies in the fact that we are not sure that to broaden the concept of science so as to talk about "native science" or "indigenous science" is indeed the best strategy to attain a goal that we wholeheartedly share with Brayboy and Castagno, to value other ways of knowing for their own sake, validity, and legitimacy.

Keywords Multiculturalism · Science education · Indigenous knowledge

A paper is relevant to the extent that it is useful, and any time we learn from reading a paper, it is clearly the case that it is a worthwhile, relevant piece of work. Thus, we want to say from the very beginning that we learnt a lot from Brayboy and Castagno's paper, and, therefore, we should stress here its importance and usefulness for those interested in science education, generally speaking, and in cultural aspects of science learning and teaching in particular.

Brayboy and Castagno urge us to critically consider the dichotomies between formal and informal science as well as between Western and Native science in the context of

C. N. El-Hani (✉)
Department of General Biology, Institute of Biology, Universidade Federal da Bahia, Rua Barão de Jeremoabo, s/n-Ondina, Salvador 40170-115, BA, Brazil
e-mail: charbel@ufba.br; charbel.elhani@pesquisador.cnpq.br

F. P. Souza de Ferreira Bandeira
Department of Biology, Universidade Estadual de Feira de Santana, KM 3, BR 116, Campus Universitário, s/n, Feira de Santana 44031-460, BA, Brazil
e-mail: fpbandeira@gmail.com

discussions about culturally responsive schooling for indigenous youth. We are both quite interested in the topic. C.N.E.H. has been doing research on multicultural education, both theoretically and empirically, for the last 6 years (e.g., El-Hani and Mortimer 2007), and F.P.S.F.B. has been working with indigenous knowledge for several years, including an involvement with educational efforts in a community of the Pankararé indians in Northeast Brazil (e.g., Bandeira et al. 2007).

We have many points of agreement with Brayboy and Castagno and at least some of them will surface throughout this commentary. But theirs is also a thought-provoking paper, and, consequently, stimulates debates about both educational and epistemological issues. In order to incite a fruitful discussion around the topics raised by the authors, we will focus initially on a specific disagreement, which is not related only to Brayboy and Castagno's paper, but to a whole body of literature on multicultural, postcolonialist, postmodernist education. To be clear from the very start about the main point of disagreement, we are not sure that to broaden the concept of science so as to talk about "Native science" or "Indigenous science" is indeed the best strategy to attain a goal that we wholeheartedly share with Brayboy and Castagno, to value other ways of knowing for their own sake, validity, and legitimacy. We also do not think that such a move can be well-supported in epistemological terms. We do agree that the discussion of the relationships between Western science and native/indigenous *knowledge*, with all the related epistemological concerns and sociocultural issues, is central to any debate about multicultural science education, no matter if we are talking about indigenous or any other kind of traditional communities. But, in our view, to move towards broadening the concept of science so as to encompass under its umbrella virtually each and every human way of producing knowledge will not help.

This issue will be the leitmotiv of this commentary, but we will also tackle two other themes in Brayboy and Castagno's paper, mostly for drawing upon their useful insights to expand on the prospects of a culturally sensitive or responsive science education (not only for indigenous but to students as a whole, since most of them do not share the basic assumptions, discourse, ideas of science, and, thus, not only science classrooms in non-Western communities but everywhere are likely to be multicultural): What should be the goals of science education and how they relate to culturally responsive schooling in a multicultural educational setting? How could we organize science education so as to not lose from sight its goals—as we understand them—and, yet, respect and empower students who come from cultural backgrounds other than the culture of science? All these issues are deeply interwoven within the argument built by Brayboy and Castagno, and were also discussed in a recent paper published by one of us in Cultural Studies of Science Education (El-Hani and Mortimer 2007).

What do we gain by broadening the concept of science?

Is it really the case that to broaden the concept of science so as to include so-called "ethnosciences" is the best way to acknowledge the legitimacy and validity of ways of knowledge other than Western Modern Science (WMS)? We seriously doubt it. But, to be sure, there is plenty of company for Brayboy and Castagno (2008) in taking this position. Many authors would entirely agree with their claim that "indigenous people have been scientists and inventors of scientific ideas for a long while." Snively and Corsiglia (2001), for instance, argue that indigenous knowledge should not be only treated as useful, but included in the realm of "real science."

Several multiculturalists argue that WMS is just one example of a number of equally valid sciences that we built throughout our history. Brayboy and Castagno quote in their paper several examples, but let us take a case in point. According to Ogawa (1995, p. 588), any "rational perceiving of reality" can be called a science. But if we assume that rationality is plural, that is, that there are many styles of reason, produced in different sociocultural circumstances, and, thus, even if there are "good modes of life where nothing worth calling reason matter" (Hacking 1983, p. 14), most humans can be deservedly called rational, then any or at least most cognitive human activities will count as science, according to Ogawa's rendering of the term. Or take the argument that "science is a way of knowing and generating reliable knowledge about natural phenomena. Other cultures have generated reliable knowledge about natural phenomena, therefore reason invites exploration of the possibility that other cultures may have different sciences" (Pomeroy 1992, p. 257). In this manner, each and every reliable knowledge about natural phenomena will count as scientific. Although this is not as broad as Ogawa's view, it is still the case that it is not only reliability that should be taken into account, but also the nature of the scientific discourse about the natural world and the set of epistemic criteria used to appraise scientific statements. It should not be denied that there are several core epistemological and ontological assumptions of WMS that are in evident conflict with core assumptions of many traditional knowledge systems. That is, there are fundamental differences between distinct ways of knowing (including WMS) that cannot be neglected, as positions such as Ogawa's and Pomeroy's can lead us to do.

What do we gain from these positions? First of all, we already have a good word to say what they mean, namely "knowledge." True, one might justify a move from "knowledge" to "science" as a designation for ways of knowing other than WMS on the grounds that, by doing so, one can counter the devaluation of those ways of knowing. But isn't it the case that in this manner we end up being committed precisely to the kind of scientistic myth about science as a unproblematically truthful, superior form of knowledge? That is, by trying to broaden the concept of science so as to include under its umbrella other ways of knowing, couldn't we in fact reinforce the "revered place" that science occupies for many people, as we would be in the end subscribing to the judgment of "other ideas and research by the same standards and values" used by the scientific community (as Snively 1995, p. 55, quoted by Brayboy and Castagno, urges us not to do)? We can see no other reason to put such a high value on simply naming a way of knowing "science." It is true that in society as a whole, and also at least in part of school knowledge, we will find scientism. However, the solution does not lie in a broadening of the concept of science, but in putting scientism directly into question. If we do so, there would be no problem in claiming that indigenous people have been knowledge producers and inventors of their own culturally based ideas for a long while. That is, we would allow the possibility that there are multiple ways of obtaining knowledge and that indigenous communities possess knowledge systems in their own rights with their own internal consistency and ways of knowing, as Brayboy and Castagno claim we should do, without losing from sight the important differentiation between distinct knowledge systems built by human beings, such as science, a variety of indigenous knowledge, religious knowledge, traditional communities' knowledge, and so forth. It is true that "we all interpret reality through a particular cultural lens" (Brayboy and Castagno 2008), but it is crucial to distinguish which lens each culturally-based way of knowing employs, including WMS.

Let us add one more reason to avoid conflating "knowledge" and "science." If we do not surrender to this temptation, we can use the word "science" to refer to a well-defined way of knowing, socio-historically built in modern societies since the seventeenth century, which acquired the kind of institutional background we see today in the turn of the twentieth century, half a century after making a definite naturalistic turn in the construction of its discourse about nature. If we conflate this term with "knowledge," we will lose this role for the word "science," since it will now refer—to use Ogawa's example—to any rational perceiving of reality, or, as we argue, to any or most human cognitive activities. And, since "science" now becomes synonymous with "knowledge," we will gain nothing in this move. It seems clear to us that this is a move in which everyone loses. Below, we will even argue that even Indigenous knowledge loses with this move. For now, let us consider the claim that there are two easy ways to get confused, one is to use the same word to say different things, another is to use different words to say the same thing. We think that to broaden the concept of science, as several authors intend to do, is to fall prey to the second source of confusion.

The problem gets even more serious when this confusion is taken to the classroom. We have no quarrels with the idea of giving room to several voices, to distinct ways of knowing, conceptions, and so on, in the science classroom. Rather, we argue precisely in the same direction. But we deeply value the need of keeping those ways of knowing (and the bodies of knowledge resulting from them) distinct in the classroom. After all, as Brayboy and Castagno themselves acknowledge, Native "science" (or, as we prefer, *knowledge*) is both similar and dissimilar to Western notions of science. And, just as they worry about assuming that there would be a single Native science and argue that one should take in due account the different ways of knowing of different tribal nations, we worry about taking all distinct knowledge systems under the umbrella of the same term, "science," making it more likely that one loses from sight their distinctiveness. If this is true, we should rather strive for clarifying which are the similarities and dissimilarities between these ways of knowing than simply conflating them in a single view about what is science. For the sake of promoting a good understanding of the nature of both knowledge and science, a highly valued goal of education as a whole, and science education in particular, we consider that to demarcate distinct ways of knowing is a crucial element.

For these reasons, we agree with Cobern and Loving (2001) that it is better to reserve the term "science" for the way of knowing typical of Western modern societies, trying to demarcate it from other ways of knowing, built and legitimized in distinct sociocultural circumstances. Despite the fact that demarcation is a very difficult philosophical problem, science educators cannot avoid it, and, even more, should assume at least some working hypothesis to advance on its treatment. After all, science curricula, textbooks, classroom discourses are all going on while we discuss the issue, and we often need to make decisions about them: should we include homeopathy in a science textbook? Can I treat farmers' or fishermen's knowledge as science in my classroom? Is it the case that science school contents should include intelligent design? These problems are all the time calling us for decision and action, and we cannot wait for a solution to the demarcation problem. We need a working hypothesis. And, indeed, we have some in the science education literature, available to be criticized, reformulated, used. We will not deal with them here, but just mention two examples, Mahner and Bunge (1996) and Cobern and Loving (2001), and refer the readers to the original works to take their own stance on their proposals.

It is clear to us that Brayboy and Castagno recognize the fact that Western and Native ways of knowing are different from each other. Then, the problem might seem just terminological for some. Even if one considers this to be the case, the problem is not a minor one for this reason. Terminological or conceptual issues are not unimportant in philosophy or science, since philosophical or scientific problems and views are also constituted by the traditions within which they are spoken about (cf. El-Hani and Pihlström 2002). We can show how terms can lead to problems by taking either of the sides in the conversation we are engaged in.

Brayboy and Castagno (and many other authors) want to use the term “science” to designate Indigenous knowledge because they consider that by naming it this way it is more likely that its devaluation is avoided. We can appreciate the motivations for this move. Indeed, since scientism is still very influential and pervasive, to call a way of knowing “science” seems to give it a sort of epistemic superiority. It is this connection between “science” and some privileged epistemic status that we should disentangle, however, and we are not walking towards this goal by applying the term indiscriminately. On the contrary, we can be rather reinforcing that very connection, as we argued above. It seems to us that the right move here would be to argue that to be different is just to be different, it does not give any privilege to a way of knowing in the face of another. As Cobern and Loving (2001) argue, “the problem is not that science dominates at what it does best: the production of highly efficacious naturalistic understanding of natural phenomena. The problem is that too often science is used to dominate the public square as if all other discourses were of lesser value” (p. 62). From this perspective, science should be properly privileged only within its own domain, namely the construction of a naturalistic understanding of natural phenomena.

Notice one first clear demarcation in this value judgment: we are talking about one particular domain of items to be explained, natural phenomena, and for many cultural traditions the world is populated by more entities than natural systems. Therefore, there is a whole range of problems to be explained, which concern supernatural realms, and, more, their relationship with the natural realm, that fall outside the domain of science. And there is no legitimate move to be made from the scientific discourse, evidence, body of knowledge to the supposed demonstration that those are a sort of pseudoproblems. If something is a problem to a cultural tradition, it cannot be denied from the perspective of another tradition. It does not mean that it cannot be criticized from the perspective of other frameworks. It can. In fact, to assume this is what takes one from a (radical) relativist position to a pluralist stance.

And, then, we have a second clear demarcation: even if we consider natural phenomena as items to be explained, WMS offers a particular kind of explanation, a naturalistic one, which is undeniably quite powerful for several human purposes. But from the fact that scientific explanations are powerful tools does not follow that they are the only tools that can be powerful.

Several indigenous cultures successfully address problems related to natural phenomena from different perspectives. For example, as described by Bandeira et al. (2002), the Maya Tzotzil people from the highlands of southern Mexico, in the Polhó municipality, can distinguish different landscape units based on several criteria. They recognize several vegetation units, soils, and microclimatic conditions. This Tzotzil ecological knowledge is critical to the design and establishment of rustic coffee agroforests (RCA), especially with regard to ecological succession. Two common routes for RCA establishment were observed: (a) from other cultivated fields (predominant route); and (b) from secondary vegetation. Coffee growing activities conducted by Tzotzil peasants, such as the protection/promotion of native trees, the cultivation of crops and N-fixing tree cultivation, the elimination of pioneer species, among others, seem analogous to ecological succession processes.

The Polhó region presents a considerable heterogeneity in its physiography and vegetation types. Moreover, the distribution of forest fragments and surface water in the area is not homogenous. All these factors contribute to a high diversity of environmental conditions and, consequently, a mosaic of suitable areas for agriculture is recognized by Tzotzil informants. This knowledge is essential to coffee production, because this crop has ecophysiological constraints that limit the environmental range where it may be successfully grown and become productive.

The Tzotzil of Polhó seems to conceptualize the environmental complexity of their territory using the same categories as other Maya Tzotzil in Los Altos de Chiapas region. They recognize and name two different landscapes in their territory: *kisin osil* ("warm farmland") and *sikil osil* ("cold farmland"). An additional intermediate or temperate physiographic zone is recognized by the Tzotzil, but not formally named. Although these categories are used in general to name the areas in Los Altos de Chiapas region with low and high elevation, respectively, they possess ethnoecological significance since they establish a conceptual link between the physical and human geography and social organization (Maffi 1999). According to Maffi, these categories do not simply designate physiographic features such as climate or vegetation, but, within the framework of the Mesoamerican hot/cold dichotomy, they refer more specifically to the differential fertility and productivity of the land, through an analogy with the healthy vs. the diseased human body. Therefore, we must understand these categories—hot country and cold country—as ethnoecological concepts inherently implying a particular manner of human relationship with the land.

Within the context of coffee production, the territorial distinction made by the Tzotzil in the region allows them to order their space in terms of ecogeography and productivity. The ecological characteristics of any given area will determine what specialized crops may be grown there, together with maize, beans, squashes, chilies, and other basic staples that historically characterize the diet of the Maya. Specialized crops such as coffee, citrus, bananas and other tropical fruits, and sugarcane are only cultivated in the *kisin osil*, although some producers may establish fields within the *sikil osil*, either as an experiment or because they do not have available fields in the "hot country." Also, this territorial differentiation allows for the identification of differences in agricultural productivity, which in part is determined by the different climatic and altitudinal characteristics of these two named zones.

This ecogeographical and landscape heterogeneity recognized by the Tzotzil should differentiate zones with optimal conditions, where coffee would be most productive; indeed, farmers take these factors into account when they decide what use will be assigned to each available plot. We can see, thus, that other perspectives on natural phenomena can be also pragmatically efficacious, often—but not always—for doing things that are different from those we do with scientific tools. But what matters here is that they are efficacious to address problems concretely faced by the indigenous communities.

Now, we have all the distinctions at hand to say two things with no diffidence—and we do think we are often too shy to say this. We can say, in our view, that WMS is the most powerful way of producing naturalistic explanations of natural phenomena that we built throughout our history! And we can also say that there are plenty different accounts of the world which are also powerful in their own ways. They are producing explanations about supernatural (or, maybe non-natural is a better term) beings and phenomena that are useful to several human cultures. And, in the face of natural phenomena, they are producing explanations that appeal to spiritual domains, going beyond naturalistic chains or networks of events.

We can embrace this pluralist view about knowledge with no fear of relativism if we are clear about the need to observe the distinctions between these ways of knowing and bodies of knowledge, and, furthermore, between the domains in which they have been shown to be successful in the past. If we do so, we think we will be relatively safe. But it is exactly these distinctions that are blurred by using the term "science" to designate each and every way of knowing.

What we lose by broadening the concept of science

Let us now argue about how terms can lead to problems by taking the side of those who—like us—are critical of the broadening of the term "science" to encompass other ways of knowing. Here, we follow Cobern and Loving (2001) in their argument that to include other ways of knowing into a broad concept of science may contribute to their devaluation, rather than to their legitimacy. What we lose in this way is the distinctiveness of other ways of knowing, and, also, their epistemic value in terms of their own validation criteria. By calling them "science," we can inadvertently set the stage for them to be submitted to the criteria of WMS, instead of being valued by their own merits. This is a game they are bound to lose, since they would have "to compete where WMS is strongest—technical precision control, creative genius, and explanatory power" (p. 62).

Is this a far-fetched fear? We do not think so. For the sake of example, consider Matthews' criticism of "some form of relativism which says that different knowledge systems are equally valid, and so there is no good cognitive reason to introduce Western science to traditional cultures" (Matthews 1994, p. 185). The basic argument is that it is not the case that different knowledge systems are equally valid, to the extent that science does not aim just at "low-level regularity-identification and prediction (e.g., that night follows day), but with explanation, grasp of unobservable causes, testability, successful prediction of the unknown, and the ability 'to grasp the truth of the matter'" (Siegel 1997, p. 100). The task, then, is not to show that the epistemic criteria employed by the scientific community stem from particular cultural contexts and traditions. Both Matthews and Siegel explicitly acknowledge that they do. But then it becomes clear how the multiscience thesis can indeed lead to a usage of such epistemic criteria to judge knowledge produced in different sociocultural circumstances, with different purposes and criteria of validity. Siegel goes on to argue:

> A significant criticism of them [particular Western conceptions, such as explanatory adequacy] would be made if it could be cogently argued that some particular "ethnic" science...offered compelling theories/predictions/explanations of natural phenomena. Could an animistic ethnic theory of volcanic activity and lava flow...provide the sort of explanation, prediction, grasp of relations among unobservables and between observables and unobservables, and depth of scientific understanding provided by Western science? (p. 100)

By insisting that Indigenous knowledge is a form of science, we can easily bring about this kind of situation, in which one is justified to demand that an "ethnic science" successfully meet the cognitive demands that the scientific community makes to knowledge. In the end, we face the danger of devaluating traditional knowledge in the very effort of advocating its value. This seems, thus, to be simply a mistaken strategy. We have no doubt there are more effective ways of recognizing and defending the importance and usefulness of traditional knowledge. After all, both Matthews and Siegel do not show any doubt about the value of traditional knowledge. Their quarrels are with the outright rejection of universalism and the attempt to include each and every way of knowing among the referents of the term "science." Matthews recognizes, for instance, the contributions of "myriad non-Western worldviews" to science, and, generally speaking, contemporary cultures, as well as "the detailed and rich empirical knowledge of animal life, astronomy, horticulture and technology that traditional societies possess" (Matthews 1994, p. 188). He takes issue with the claim that the achievements of traditional cultures are "scientific," not with the claim that they are "obviously important" (p. 191). It is true that Matthews seems to be committed to the idea of a epistemic superiority of Western modern science, which we argue one should avoid, but it would not be fair to merely say that he does not recognize at all the relevance and value of traditional knowledge.

This scenario makes us think if it is really the best move in this debate to insist on treating traditional knowledge as "scientific," as a way of supposedly establishing its value. Matthews' and Siegel's arguments point out to important differences between WMS and Indigenous or traditional knowledge. These differences are, symptomatically, also mentioned by Brayboy and Castagno when they argue that "Native science does not attempt to generalize observations to universal laws or to combine observations in order to make predictions about the nature." We cannot take Indigenous or traditional knowledge to be inferior because it does not build models with the abstract, generalizing nature of scientific models, or does not aim at the same kind of predictive power as science do. Nevertheless, we can legitimately highlight the differences between these ways of knowing and, thus, argue against conflating all of them as referents of the term "science," taken as an "umbrella term."

Matthews' requirement that a number of criteria should be fulfilled if one wants to call some way of knowing "science" and some body of knowledge "scientific" seems justifiable, to our understanding, in the face of the kind of knowledge built by the scientific community, as a historically constituted social group, building a particular kind of culturally based but powerful account of the natural world, and appraising it by means of a set of historically established criteria. Notice that we are not saying that the way this community builds knowledge, the knowledge built, or the criteria employed to appraise cognitive statements are epistemically superior to any other body of approaches, ideas, statements, criteria. We are just saying that they are different, and should be kept different, for the sake of clarity about the nature of knowledge and the nature of science. Notice also that we are not claiming that what is distinctive of science is the use of a particular single method, "the scientific method." It is very controversial in the current philosophical landscape, to say the least, that "mainstream Western science" can be characterized through the scientific method. Here, we side with Brayboy and Castagno's suspicion about the existence of such a single scientific method (see also, e.g., Bauer 1994). A methodical approach to the study of the world is an important part of science, but there is not one single method that each and every scientist should follow. Rather, science proceeds through a variety of "methods," or, as we might prefer, "styles of scientific reasoning" (Hacking 1983, p. 56), including the geometrical, the model-building, the statistical, the hypothetico-deductive, the comparative/evolutionary, the genetic, among other styles.

Roads to objectivity (not presumed)

Brayboy and Castagno conceive objectivity and universality as "presumed" characteristics of science. We will argue here that we can find both in Western science, and elsewhere, provided that we reinterpret what we mean by "objectivity" and "universality," and carefully sets them apart from scientism. We will not say much about universality, since we decided to focus on objectivity, for the sake of our argument in this paper.

As to universality, we put into question the very dichotomy local-universal. The general idea is that the question of whether science is local or universal does not have an "either-or," but a "both-and" answer. Scientific knowledge can be treated as both local and universal, without losing from sight that scientific knowledge—or, for that matter, any body of knowledge—is socially constructed. Science as way of knowing is local because it is a product of particular sociocultural and historical circumstances in Western Europe (although under multicultural influences, such as those stemming from Arabian cultures). Nevertheless, there are good reasons to claim that it is also universal, since, epistemologically, science aims at building if not universal, at least quite general models, which abstract away from several details of the phenomena at stake to build representations that get under their umbrella large classes of phenomena taken to be similar in nature, from the perspective of a given theory. And, besides this epistemological argument, we can also build a sociological argument for the universality of science, based on the transnational, cross-cultural nature of the scientific endeavor and community, which, despite being the end product of a local, Western European process, are now spread throughout the world, and, even though no scientist can be free from the influence of the culture in which she was born, scientists all around the world show a remarkably similar body of attitudes, values, practices, knowledge. All this contributes for a claim of universality for science, but caveats should be in place, since to be universal should never be taken as meaning or entailing to be epistemically superior. Furthermore, science is not only universal, but also local, to our understanding, and, if we take, for instance, the sociological side of our argument, it is not only science that is found across cultures and nations, but also other institutions, such as several religions.

We will appeal to Kuhn to address an issue that will naturally lead us to discuss the idea of objectivity, namely the epistemic criteria that guide theory choice in science. It is particularly relevant to go for Kuhn here, since he has been often taken as a basis for developing radically relativistic accounts of knowledge that he himself did not endorse, through what Hacking (1983, p. 13) calls "the popularized Kuhn of *Structure*." He was also taken as a ground for putting under siege the idea of objectivity and rationality in science—something that is quite often done by multicultural theorists, researchers, and educators—and, thus, his work is quite adequate to address the claim that scientific knowledge can only have a "presumed objectivity."

Kuhn himself showed his disagreement with a reading of his arguments that lends support to rampant relativism. He regarded such interpretations of his position as persistent misunderstandings (Kuhn 1977, p. 321), and wrote a paper symptomatically entitled "Objectivity, value judgment, and theory choice" to explain at greater length and precision what he had in mind while arguing about theory choice, or, as he prefers, conversion.

In this paper, Kuhn argues that scientists use a number of criteria to judge theories, which mediate at least partially the process through which theories come to be accepted by the scientific community. It is not that each and every scientist ponders about these criteria and applies them to theories that they keep in mind together and compare point by point while being converted to a scientific theory. One of the reasons why Kuhn prefers to speak about theory conversion, not theory choice, lies in the fact that such a point-by-point comparison between theories does not happen.

But what are the criteria presented by Kuhn? He mentions five criteria. First, theories should be accurate, that is, they should fit existing experimental and observational data (not only quantitatively, but also qualitatively), or, alternatively, they should show empirical consistency, even though the relationship between theory and evidence is far from being simple. Time-honored criteria to appraise scientific knowledge, such as predictive and explanatory powers, depend on accuracy. Second, they should also show theoretical consistency, that is, they should be consistent both internally and externally, when compared to other currently accepted theories applicable to related aspects of nature. Third, scientific theories should be broad in scope and rich in consequences, i.e., science strives for coherence and systematicity in the construction of its body of knowledge, even though it may be not always successful in properly integrating scientific knowledge. Fourth, scientific theories should be simple, organizing facts in an intelligible way, bringing order to phenomena that would seem in its absence individually isolated and, as a set, confused. Fifth, they should be fruitful, heuristically powerful, leading to new knowledge about the world.

Kuhn appeals, thus, to five standard criteria for evaluating the adequacy of a theory, which provide a shared basis for theory choice and are not really at odds with previous philosophy of science. The difference between previous approaches to theory choice and Kuhn's position lies in the fact that he argues that, individually, criteria for theory choice are imprecise, in the sense that "individuals may legitimately differ about their application to concrete cases," and, furthermore, "when deployed together, they repeatedly prove to conflict with one another" (p. 322). The difficulties in applying those criteria lead to a situation in which, when two scientists have to choose between competing theories, even if they are both fully committed to the same criteria, they may nevertheless pick different theories. If one wants to explain the choices made by particular men at particular times, Kuhn argues, "one must go beyond the list of shared criteria to characteristics of the individuals who made the choice," dealing with "...characteristics which vary from one scientist to another" (p. 324).

To understand the choices that particular individuals made at particular periods of the history of science, we should understand how those individuals undergone an enculturation process to become part of a scientific community. Furthermore, we have to understand how several processes of negotiation took place inside a scientific community to comprehend how theories changed. Does this mean that the history of theory change in science is a historical process in which no objective criteria play any role? Is there no possible touch of rationality and objectivity in this process? Kuhn does not think so (and we agree with him). He just wanted to argue, first, that there are canons "that make science scientific," but, second, "they are not by themselves sufficient to determine the decisions of individual scientists" (pp. 324–325). The shared canons of the scientific community to which Kuhn appeals are not sufficient, but they can be *necessary*, or, if one does not want to be committed to a stronger position to this effect, at least *important* canons for theory choice, which make science "scientific."

What are the consequences of Kuhn's view about the criteria for theory choice for the debate about objectivity and subjectivity in science? His point is that every individual choice between competing theories depend on a mixture of objective and subjective factors, or shared and individual criteria" (p. 325). Thus, he combines in his argument shared criteria (which his critics called "objective") and individual criteria (which were called "subjective"). He interestingly moves from seeing these epistemic criteria not as *rules*, but rather as *values*. That is, these criteria do not function as rules that might determine choice, but as values, which only influence it. He speaks of "values guiding scientific choice," not "rules dictating choice" (p. 333). This explains, then, why two scientists committed to the very same criteria can make different choices in particular situations. But Kuhn adds that these different choices do not suggest that "the values scientists share are less than critically important either to their decisions or to the development of the enterprise in which they participate" (p. 331). Furthermore, we can even take from his arguments that he does not derive from their undeniable sociocultural and historical nature a denial of the objective and rational nature of decisions grounded on such criteria. He insists that

> Values like accuracy, consistency, and scope may prove ambiguous in application, both individually and collectively; they may, that is, be an insufficient basis for a *shared* algorithm of choice. But they do specify a great deal: what each scientist must consider in reaching a decision, what he may and may not consider relevant, and what he can legitimately be required to report as the basis for the choice he has made. (p. 331).

That is, even though there is no shared algorithm of choice, the criteria themselves are shared by scientists who can act rationally on their ground, and even be able to legitimately report the reasons for their theory choice, even in cases they cannot completely articulate these reasons. Therefore, we should not necessarily derive from the historical nature of the epistemic criteria used by science that decisions grounded on them should be irrational or subjective. These criteria do guide scientific choice, even though they do not determine it. This is the key issue in Kuhn's arguments and we share his view.

In the end of his paper, Kuhn reveals his discomfort with the terms "objectivity" and "subjectivity," and argues that language has gone astray in the debates about *Structure*, due to a conflation between two distinct uses of "subjective," one in which this word is opposed to "objective," another in which it is contrasted with "judgmental." In his view, his critics appeal to this second sense when they describe the idiosyncratic features to which Kuhn resorts to describe theory choice as "subjective." But, then, when they claim that Kuhn deprives science of objectivity, a conflation of the two senses of "subjective" would take place. Therefore, we can take Kuhn as claiming that, even though guided by values, not algorithmically determined by rules, theory choice in science is still objective. What does he mean by the word *objective*?

Kuhn infers that his critics suppose he takes theory choice to be a "matter of taste," to which the term "subjective" is standardly applied. But, he argues, they lose from sight that matters of taste are undiscussable. If two scientists disagree about a theory choice—we can take from Kuhn's arguments—what is discussable in their decisions are not characterizations of their internal states, the fact that one likes the theory, the other does not. What can and often is discussed about their decisions is the judgment they offer about the theories, a judgment that is guided by values shared by the scientists, but applied differently to that specific situation. After negotiation and all the rest, we still see a case in which there are criteria being applied and there is a judgment being done. We do not have a subjective situation in the sense that it is not judgmental, just a matter of taste.

We can also see that there is a judgment being done from the fact that "scientists may always be asked to explain their choices, to exhibit the bases of their judgments" (p. 337). Their judgments are eminently discussable. From these arguments, Kuhn concludes that, if his critics introduced the term "subjective" in a sense opposed to "judgmental," suggesting that he makes theory choice undiscussable, just a matter of taste, they have seriously mistaken his position. From the fact that he treats criteria for theory choice as values that can only guide, not determine, that choice does not follow that there is no judgment being done, which can be critically analyzed, properly justified, and so on: "Where factors dependent on individual biography or personality must be introduced to make values applicable, no standards of factuality or actuality are being set aside" (p. 337).

Kuhn states that his discussion of theory choice might indicate, at most, "some limitations of objectivity, but not by isolating elements properly called subjective" (pp. 337–338). These are very important elements in Kuhn's works, given the role they unexpectedly (to his own author) played in nourishing radically relativistic and a whole plethora of other kinds of views. Notice that he does not deny objectivity, and, furthermore, that he explicitly avoids taking theory choice as a subjective endeavor.

We also think something fruitful can be said about objectivity by tying it not to propositions, but to human practices, as Shrader-Frechette and McCoy (1994) argue we should do, based on what they call a "Wittgensteinian insight." This was an insight they derived from Wittgenstein's statement that "giving grounds...is not a kind of *seeing* on our part; it is our *acting*" (Wittgenstein 1969, p. 204). We are not in a position to say, for some time now, that a proposition is objective because it mirrors some reality out there in the world, because it amounts to some mind-independent beliefs about the world. Since Kant, it became clear that truth cannot consist in some correspondence to an external, mind-independent reality. But, yet, it seems important to say, in our human practices, when a statement is objective or not. How can we do so? We can follow Shrader-Frechette and McCoy in their "Wittgensteinian" insight and move from propositions to practices, saying that objectivity concerns the search for impartiality in our actions, i.e., for methods and procedures which aim at avoiding biases, at least to some extent, and also at critically appraising biases. Accordingly, a proposition built through such practices would be taken, secondarily, as objective.

It is evident that scientific knowledge reaches, in these terms, a high degree of objectivity, due to its public nature and to the use of a series of (far-from-being-perfect) procedures of mutual rational control by the scientific community, such as systematic criticism of theories and hypotheses, methods and evidence, through referee systems, project evaluations, meeting presentations, etc. But, to be sure, this kind of objectivity is not exclusive of science. Quite obviously, critical thinking and action are part of many human practices of knowledge construction, such as, say, philosophy, logic, theology, and so on. Therefore, we have here an interesting view of objectivity, which does not fall prey, to our understanding, to a view of the mind as a supposed mirror of nature, and does not lend itself to a value distinction of science as some superior knowledge, while it properly recognizes the powerful nature of this way of knowing (alongside with others). In sum, in these terms, we do not think science is only "presumably" objective.

Why should we value indigenous or traditional knowledge?

Matthews (1994) appeals to at least part of the standard criteria mentioned by Kuhn in his argument against treating diverse knowledge systems as "scientific." If we apply those criteria, it will be clear that Indigenous knowledge does not satisfy many of them. But is this surprising? Not really. Those criteria were built throughout the history of WMS, and there is no reason why other ways of knowing should observe them. It becomes clearer now why we agree with Cobern and Loving in that other ways of knowing are, generally speaking, led to play a game they are bound to lose if we call them "science." This opens the door for the criteria used to appraise scientific achievements to be impinged upon these different ways of knowing, and they are not likely to hold under them. Kuhn's arguments themselves suggest that different epistemic criteria can be used by different cultures in order to judge bodies of knowledge. He only assumes that, very roughly speaking, if the list of relevant values guiding scientists' theory choice is kept short, and if their specification is left vague, values such as accuracy, scope, and fruitfulness are "permanent attributes of science" (Kuhn 1977, p. 335). But he does not require at all that these scientific criteria be employed beyond scientists' theory appraisals, in order to judge other bodies of knowledge, produced by other ways of knowing. After all, he considers that "...there are societies with other values and that these value differences result in other ways of life, other decisions about what may and what may not be done" (p. 331) As much as different disciplines can be characterized by different sets of shared values, different ways of knowing, and here Kuhn refers to literature and plastic arts, also share different sets of values, when compared to science (p. 331). But, naturally, for different sets of criteria, we will have different appraisals of the validity of knowledge. We can be justified, then, in claiming that Indigenous or traditional knowledge is legitimate and valuable on the grounds of its own epistemic criteria, and, thus, calling it "science" can just contribute to take it apart from the very context in which it finds its legitimacy.

Why should we value Indigenous or traditional ways of knowing and bodies of knowledge? In our view, not because they are "ethnosciences" or "ethnoscientific." This does not seem that different from an uncritical acceptance of the myth of modern science. Traditional bodies of knowledge should be valued for what they are, as legitimate constructs, powerful in their own domains, valid according to epistemic criteria built in their own cultural backgrounds. Let us move to familiar terrain here and argue for the deep value of indigenous knowledge in these terms, by addressing a particular case, namely the Pankararé indigenous community in Northeast Brazil.

The Pankararé's ecosystem management brings about a landscape dynamics that makes it possible to maintain a significant part of the forest cover in their territory, decisively contributing to the survival and social reproduction of this indigenous people in one of the areas with greatest environmental frailty in the Brazilian semi-arid region. Studies conducted in the beginnings of the 1990s by Bandeira et al. (2007) described the knowledge, management practices, and cultural and spiritual values which, when taken together, partly explain how this indigenous people interacts with its environment.

Briefly, we can say that two dimensions operate simultaneously during the Pankararé's decision making about how to manage soils, vegetation, and particular animal and plant resources: both a symbolic and a cognitive dimension, mediated by a way of perceiving space that is proper of this Indigenous group, and, ultimately, regulated by a model of organizing land property. Thus, space is organized both by the Pankararé's worldview, which results in a symbolic mapping of its territory through the treatment of landscape features as monuments inhabited by entities called "encantados" (the enchanted), and by the different regimens of land property (communal and familiar). In this manner, two kinds of constraints function in the process of decision about ecosystem management among the Pankararé: on the one hand, constraints stemming from a model of property organization that is characteristic of peasantry Indigenous societies, but result from a particular process of change that took place in the social and productive organization of indigenous groups originated in this Brazilian semi-arid region; on the other hand, social norms derived from the collective acceptance of a symbolic space coding, related to constraints imposed by beings who inhabit a superhuman and supernatural realm, the enchanted. We can even speak of a symbolic-spatial Pankararé epistemology, which defines the coexistence and connection of worlds that are both expressed in spatial terms, but are complementary rather than antagonistic.

Nevertheless, the Pankararé's ecosystem and natural resources management is also based on their ecogeographical knowledge, which makes it possible to organize their territory according to units defined by socioenvironmental criteria. They identify three kinds of units—*raso*, *brejo*, and *sertão*—and correlate to these units different types of soil (weak and strong soils) and also kinds of vegetation that indicate the viability of certain cultivation and other productive activities. We have here a sophisticated cognitive process, through which the Pankararé apprehend the geographic, ecological, geomorphological, and pedological variability of their territory. This knowledge interacts with and is ultimately regulated by the property regimen characteristic of the Pankararé society.

In sum, the Pankararé's ecosystem and landscape management is grounded on perceptual, cognitive and symbolic bases, which interact in a complex manner and result in an efficaciously mapped territory.

The Pankararé's knowledge can be seen as legitimate, powerful, and valid under the light of a set of criteria which are at least partly different from those used by WMS, as shown by its symbolic basis, among other features. But so what? It does not really matters if the Pankararé's knowledge would not stand in the face of (our) scientific criteria. Why should they stand? One possible reason to argue for this sort of "test" of Indigenous knowledge lies precisely in the insistence of many multiculturalists and other thinkers in calling it "science." Therefore, if we want to value indigenous knowledge—as we do—to call it "science" will not help. Quite to the contrary.

It is true that scientific knowledge and any indigenous knowledge, such as the Pankararé's, are typically (but not always) efficacious in doing different things. Nevertheless, no epistemic superiority follows from acknowledging this, just the conclusion that they are different bodies of knowledge. They are both valuable, since what they allow us to do is important for humans, no matter if they do not share the same culture. We should be capable of arguing for differentiating between diverse ways of knowing, without taking one to be superior to the other in general terms (not in the context of a well defined problem, framed in a specific sociocultural circumstance), and never arguing for the hegemony of any particular form of knowledge. In short, no epistemic privilege should be ascribed to Western science, and one cannot lose from sight the value of not only scientific knowledge, but also other ways of knowing in the sociocultural environments in which students and their communities live.

As Southerland (2000) reminds us, an important source of confusion in the multiculturalism debate is the conflation of universalism and scientism. It is not universalism or the traditional account of what is science in itself that leads to a devaluation of other ways of knowing, but scientism. Even though scientism and universalism often walk hand-in-hand, it is fundamental to bear in mind that they are different positions. Scientism diminishes the value of other forms of knowledge by blatantly promoting the hegemony and superiority of science, but one can differentiate science from other ways of knowing without being committed to these claims of hegemony and superiority, as we argued above. Here, we follow Cobern and Loving (2001) in arguing that the event that WMS dominates at the domain in which it offers its most fruitful and efficacious outcomes, the naturalistic understanding of natural phenomena, is not a problem. The problem rather appears when scientific ideas are used to dominate the public square in all its domains, as if all other discourses were, generally speaking, of lesser value. Or, as Smith (1999, quoted by Brayboy and Castagno) argues, the problem lies in taking science as an all-embracing method for gaining understanding of the world. The scientific approach is not the best in all domains of human lives and activities. Other discourses show legitimacy and value in domains in which science is not only unsuccessful, but even inappropriate. The dream of a purely scientific view of reality should be dispensed with, because "science is but a part, though an important one, of man's effort to understand himself, his culture, his universe" (Greene 1981, p. 8).

Indigenous knowledge and its spiritual basis

Snively and Corsiglia (2001) argue that scientists refuse to recognize indigenous knowledge as "science" due to its spiritual basis, and go on to rightly argue that "spiritual explanations often incorporate important ecology, conservation, and sustainable development strategies" (p. 23). We find the same arguments in Brayboy and Castagno. Spiritual explanations are really important for the ecological strategies of indigenous communities. If we take the Pankararé as an example, we can see, as discussed above, that space is not homogeneous for them, and, moreover, that its heterogeneity is grounded not only on a human, but also on a spiritual world. They differentiate space based not only on the value resulting from diverse ways of using it, but also on its symbolic meaning, since this indigenous group reaffirms its ethnicity and individuality in its territory. Its space can be seen as a referential space. And it is the social construction of space by this indigenous people—its singular perception of it—that constitutes the starting point for appropriating all natural resources (soil, vegetation, fauna, flora, water and mineral resources). A sort of "management plan" is defined a priori through a collectively shared and culturally grounded mental map of space. Indeed, culture leaves its lasting mark by means of a characteristic toponymy, i.e., through place-names that keep the traces of a way of symbolically organizing the portions of the territory in which humans and the enchanted should inhabit and "negotiate." Space management is based not only on an economical and ecological rationality, but also on a symbolic rationality which all the Pankararé should observe, unless they want to be punished by sanctions imposed by both humans and the enchanted.

We cannot really understand the Pankararé's knowledge without taking in due account the enchanted—also called "enchants," "forest little grandfathers" (in Portuguese, "Avozinhos do mato") or "gifts" (in Portuguese, "dons") —which are beings who do not belong to the natural world. These are spirits who protect the Indians themselves, and also plants, animals, waters, and even relief features. During their rituals, such as the "Dance of the Praiás" ("Dança dos Praiás"), a shamanic trance connects the Pankararé directly to the different worlds. Only men are potentially allowed to dress the ritual clothes made with fibers from *Neoglaziovia variegata* (traditionally named "croá") in order to concentrate and participate in the Dance of the Praiás. During the trance, the enchanted diagnose diseases, prescribe medicines from the Caatinga, the biome found in this region (somewhat similar to the African savannah), and regulate the use of natural resources. They can, for instance, allow hunting and regulate where and when it can be performed, providing information about how many animals are in the Caatinga and how many can be hunted or gathered.

In this manner, the spiritual world plays a central role in shaping the way this Indigenous people interacts with its environment. And there is evidence that they are capable of exploiting natural resources in a sustainable way. In a study about landscape dynamics in the Pankararé's territory, Bandeira et al. (2005) compared Landsat images from 1987 and 2001 in order to identify changes in the patterns of soil usage and the degree of management of vegetation areas. These changes can be related to the different property regimens in the indigenous territory, but are connected, above all, with other factors, such as the ecogeographical units at stake (high or low lands) and the way the Pankararé limit the exploitation of certain areas that they regard as monuments, since it is there that the enchants come together. By comparing images of the Pankararé's territory separated by almost 15 years, Bandeira et al. (2005) showed that, generally speaking, in most of it forest cover is relatively conserved (ca. 70% of a total of 50,000 ha), although in some parts, environmental factors associated with human activities resulted in a decrease in vegetation density.

There can be no doubt, then, that indigenous knowledge is valuable. If we drop the urge for calling it science, it is more likely that scientists' resistance go with it, particularly, if we are successful in showing the legitimacy, efficacy, validity of this knowledge for ecological reasons, among others. This is a better argument than insisting on a name. We are particularly sympathetic with Deloria's (1992) idea that we should speak of "metaphysics" rather than "science" or "religion" when we deal with indigenous peoples' knowledge of the world, which is deeply interwoven with their spiritual traditions.

Snively and Corsiglia (2001) stress the importance of spirituality for the construction and conservation of indigenous knowledge. Similarly, Cobern and Loving (2001) argue that indigenous knowledge is embedded in a spiritual system of meaning that cannot and should not be ignored. Brayboy and Castagno also emphasize the importance of both the empirical and the spiritual realms in Indigenous processes of knowledge construction, despite the differences between indigenous ways of knowing. All these arguments suggest that, when indigenous knowledge develops to the extent that it becomes systematic, to different degrees in different cultures, the kind of structure reached is rather different from that we observe in scientific knowledge: indigenous knowledge may be systematized, for instance, around classifications of living and non-living entities or around myths about the spiritual domain and how it relates to the natural world. It is not the case that indigenous knowledge is always unsystematic, since it may amount to an entirely different kind of systematic knowledge, when compared with scientific theories. But, above all, to recognize the central role of the spiritual system of meaning in indigenous knowledge, among several other aspects of indigenous culture, makes it immediately clear how important it is to teach science in native communities in such a manner that their culture is both respected and valued, and, quite importantly, can be present in the science classroom. We should now move away from the basic disagreement on which we focused up to this point and turn to some of our many points of agreement with Brayboy and Castagno.

How can we justify science teaching in traditional communities?

Brayboy and Castagno characterize culturally responsive schooling as an educational practice firmly grounded on Indigenous heritage, language and culture, aiming at the development of culturally-healthy students and communities. Moreover, they focus on the qualities and practices of culturally responsive educators, curricula, and schools, which, unfortunately, are not successfully met in many situations. First of all, let us note that there are many similarities between what El-Hani and Mortimer (2007) called a "culturally-sensitive science education" and the proposal of culturally responsive schooling for the Indigenous youth. Both proposals lend support to the necessity of always asking why and what for we teach science in a given social circumstance, and, once a option for science teaching was made, what are the goals of science education and how can they be compatible with respect for cultural difference and several other worries of multicultural science education.

How can science teaching be justified? We do not intend to consider here all the threads that can be taken into account when discussing this question. We will begin by addressing one of the "intercultural imperatives" that Boaventura de Sousa Santos enunciates: "Since all cultures tend to distribute people and groups according to [...] competing conceptions of equality and difference, subjects and social groups have the right to be equal when difference makes them inferior, and the right to be different when equality uncharacterizes them" (Sousa Santos 2001, p. 11). We believe that science education can be justified in many traditional communities because a lack of access to opportunities to understand scientific knowledge is a difference that makes them inferior.

Sousa Santos rightly writes that this imperative is hard to reach and keep. True. But it seems to us that this is a tight rope that multicultural educators cannot avoid. Banks' (2008) discussion of the goals of multicultural education offers a clear view of this tight rope: "A major goal of multicultural education is to provide all students with the skills, attitudes, and knowledge needed to function within their community cultures, within the mainstream culture, and within and across other ethnic cultures" (p. 2). In another passage, Banks writes:

> Another important goal of multicultural education is to help individuals from diverse racial, cultural, language and religion groups to acquire the knowledge, attitudes, and skills needed to function effectively within their cultural communities, the national civic culture, their regional culture, and the global community. (p. 5).

Multicultural education should be, in these terms, part of an effort to provide all citizens of countries marked by diversity (all or at least most countries in the world) rich opportunities to participate in and experience other cultures, contributing to their fulfillment as human beings. It should also prepare the students to be effectively integrated and functional in a culturally and ethnically diverse, and, more than that, deeply troubled and ethnically polarized nation and world. This certainly applies to Indigenous peoples. Also in their cases, we can say that, if they know the world only from their own cultural perspectives, they are being denied important elements of human experience. If their education does not include opportunities for them to experience other cultures, including the scientific culture, it will be in the end contributing to culturally and ethnically encapsulate Indigenous students. As Banks writes, "a key goal of multicultural education is to help individuals gain greater self-understanding by viewing themselves from the perspectives of other cultures" (p. 2). This is one of the reasons why we think that, if scientific ideas are taught in a culturally responsive, sensitive manner, they can play a part in empowering rather than devaluing Indigenous peoples' culture and identity.

Moreover, multicultural education should not lose from sight the need of giving all students—including non-Western students—opportunities to master the skills necessary to function successfully in highly technological, knowledge-oriented societies, as well as in societies that cannot be characterized in these terms, as it is the case of many traditional communities, but nevertheless stand in relatively close relationship with those societies, including, for instance, cultural, power, economical relationships.

Brayboy and Castagno (2008) are likely to agree with this view about the goals of multicultural education, as they seem to concur with other scholars who desire that "Indigenous youth become fluent in multiple ways of knowing," and, consequently, view culturally responsive schooling as aiming at producing "students who are bicultural and thus knowledgeable about and competent in both mainstream society and tribal societies." This is even presented by them as the most fundamental goal of culturally responsive schooling. They also argue that schooling is culturally responsive when it makes sense to students who are not members of the dominant social group, and, moreover, which intends to build a bridge between students' cultures and the school in order to attain improved learning and school achievement.

In the case of the Indigenous group on which we focus in this commentary, we should ask what makes sense to the Pankararé with regard to schooling. We can see, then, that what this Indigenous people wants comes close to the goals put forward by Banks, and, also, that they want to get access to equality since their exclusion from the world of scientific knowledge is also a means of social exclusion. As Yup'ik and Iroquoian communities, who want their youth to learn about multiple worldviews and be able to operate within both the dominant and tribal communities (Kawagley 1990; Martin 1995), the Pankararé indeed express their desire to have access to mainstream education, including science education, in a manner that gives support to the way we conceive of the goals of multicultural education. This is a desire of not only the Pankararé, but of many Brazilian Indigenous people, which has resulted in a movement for inclusion in several levels of the educational system, including public universities, with the additional demand that such education should be multicultural in its nature.

This Indigenous people clearly sees that its children need to master both mainstream culture and their own culture in order to function successfully within mainstream institutions and be included in our current world, deeply influenced by technology and science, without facing cultural alienation from their families and community. In this manner, Indigenous students may be able to become successful in school and in their relationships with Western societies without facing what Fordham (1988) called a "pyrrhic victory," an inclusion into society that entails alienation from self, family, and community, a victory marked by considerable pain and losses. Moreover, if multicultural education is properly put into practice, it may be an effective, transformative, and critical citizenship education that helps students acquire more than knowledge, skills, and values potentially conducive to their own success or even the success of their community. Banks considers that such education can stimulate students to acquire cosmopolitan perspectives and values required to work to attain equality and social justice for people all around the world. It would be thus an education for engagement and tolerance much needed in our politically, economically, and also culturally torn world.

The Pankararé want to know how to deal with their own culture, the mainstream culture, and, above all, how to move across these different cultures. They want to build the bridges mentioned by Brayboy and Castagno (2008), they want, as these authors also write, "to become cultural border crossers with the goal of learning the culture of Western science in order to use it." It is evident, then, that the challenge is to teach science as standardly defined, not some reinterpreted "science" that might be an umbrella for virtually all ways of knowing built by humans. It is also clear that the goal is to teach science without leading to cultural erosion. How can we meet the challenge of a multicultural education that can lead to understanding of scientific ideas without denying the students' own cultural background? We do not have the answer, but we do have some ideas that may contribute to face this difficult problem.

But, before turning to them, let us say, in sum, that we think one can justify science teaching in many traditional communities because in current technoscientific societies, and also in many societies that cannot be characterized as technoscientific, but are in relatively close interaction with Western societies, failure to learn science is a factor leading to social exclusion. It is, in Sousa Santos' terms, a difference that contributes to a situation in which people coming from different cultural backgrounds are in an inferior position in many different social circumstances. This is the case for many Indigenous tribes, in Brazil and in several parts of the world, with the possible exception of only rather isolated communities.

Therefore, it is likely to be necessary to teach science in many indigenous communities, provided that these communities autonomously decide to include science education in their schooling process, since we subscribe to the view that they should have a significant degree of autonomy.

Teaching science in traditional communities: some ideas about 'How?'

When teaching science to indigenous students, it is our view that we should always take in due account their worldviews in the science classroom, practicing what Southerland (2000) called "instructional multicultural science education" (MSE). In this case, one does not broaden the concept of science, but strives for building a classroom atmosphere in which the voices of students from different cultural backgrounds can be heard, in which a variety of ideas, stemming from different sociocultural matrices, is discussed in the classroom. It is also the case that, in an instructional multicultural science classroom, the goal of stimulating students to understand scientific ideas is never lost from sight. After all, as the Pankararé remind us, that's why their children are there for, to have access to the white men's knowledge, not to a confusing mixture of ideas from different cultures. As El-Hani and Mortimer (2007) write:

> A dialogue between different ways of knowing is highly advisable in science classrooms, but it should not collapse into a mere confusion between them, in which borders between cultures, approaches to nature, domains of application, etc. are simply blurred. In this way, nothing valuable will be really learnt, since arguments and reasons will be simply dissolved into a general hodgepodge. (p. 683)

This brief characterization of instructional MSE allows us to be explicit about the kind of shift we advocate when proposing a culturally-sensitive science education. It is mostly on the nature of classroom interactions, and, thus, on teachers' practice, that we focus when considering the kind of change that is needed. Nevertheless, it is important to remind, as Brayboy and Castagno do, that also the nature of the school–community relationship should change for education to be responsive to the cultural background and needs of Indigenous communities. It is also a central issue to consider the different learning styles of Indigenous students, which can be closely related to their cultural experiences. A teacher who works with indigenous students must be attentive, thus, to several factors that may hinder their learning, from clashes between basic assumptions of the students about the world and our knowledge of it, which can be at odds with those assumptions that guide the construction of scientific knowledge, to their styles of learning, which can make it difficult for them to succeed in the typical kinds of tasks that constitute school practices.

Brayboy and Castagno have many useful things to say about the contribution to the improvement of indigenous students' achievement levels and interest in school that can follow from culturally responsive schooling, more aligned with students' cultural background, experiences, and worldviews, or about how teachers can meet this challenge in culturally responsive schooling, particularly with regard to teachers' dispositions, attitudes, values, and knowledge. Focusing on the latter, we basically agree with most of their arguments to this effect, and, indeed, what we advocate concerning instructional MSE demands such a particular set of teachers' characteristics. Consider, for instance, how the proposal of dialoguing with students about several ways of knowing without simply mixing them up, keeping in view their different epistemological, methodological, and ontological bases, demands a teacher with a solid background on historical, philosophical, and cultural dimensions of both science and other ways of knowing. It is certainly difficult to educate teachers with these characteristics, and we do not seem to be particularly successful in doing so all around the world, as Brayboy and Castagno show in the case of the US and we can say in the Brazilian case. Be that as it may, we do think that this is a challenge to be met, and lessening the demands on teachers capable of carrying out science education in a culturally responsive or sensitive manner will not make us advance in tackling this difficult endeavor.

These ideas lead one to focus on how discursive interactions should take place in science classrooms. It is necessary to give room to students' voices in the classroom, no matter if they will speak about scientific ideas or not. From the perspective of instructional MSE, it is a central issue that ideas from other bodies of knowledge can and should get expressed in the classroom. It is indeed important that all voices in the classroom are recognized and that Indigenous students are not silenced in the schooling process, so that they can face more meaningful education experiences and be empowered through them, precisely as Brayboy and Castagno advocate. A science teacher should not, indeed, favor a view of science as a hegemonic knowledge system, but must rather come to see that there are multiple *legitimate* ways of knowing that can enter the science classroom. But how should they enter? How should we include or integrate students' worldviews and epistemologies into science education? Is it necessary to broaden the concept and the curricula of science to build a culturally sensitive or responsive approach to multicultural science education? Or instructional MSE is enough?

We argue for this second approach, since we believe that instructional MSE makes it more likely that the teacher does not lose from sight that she should aim, after all, at promoting Indigenous students' understanding of scientific ideas. And, also, that the presumed superiority of WMS should be challenged in the science classroom. The problem then becomes: how can a teacher promote students' understanding of scientific ideas and, at the same time, avoid disrespecting their cultural background, serving as a factor of cultural erosion, hindering students' empowerment, and/or leaving the supposed epistemic superiority of WMS unchallenged? Or, else, how can we contribute to students' border crossing into the culture of science (e.g., Cobern and Aikenhead 1998), or enculturation (Mortimer 2000), without promoting acculturation?

First, it is important to take into account that the indigenous communities should have a voice in the very decision of including science education as part of the schooling of indigenous youth. After all, science education is always a factor of cultural change and can even be a cause of cultural erosion (particularly, if not carried out in a culturally sensitive manner). And, needless to say, to take a decisive role in this kind of choice is a fundamental element of Indigenous peoples' autonomy. Consider, for instance, the tensions between the nature of scientific knowledge and Navajos' state of *hozho* (a balanced life in harmony with everything around you), discussed by Brayboy and Castagno. Science is *not* only a matter of fragmentation and lack of connectedness, as those authors say, but, anyway, we do think that the kind of integration with nature to which indigenous peoples such as the Navajo or the Pankararé aspire is not a goal shared by the scientific way of knowing, which unsurprisingly has other goals. It seems, thus, that conflicts between Native ways of knowing and WMS can indeed happen in the science classroom, and may lead students to avoid WMS or even put into risk their commitment to their own culturally-grounded knowledge. Therefore, it may be even the case that science is not to be taught in particular indigenous communities. But when is it justifiable to teach science to Indigenous children and teenagers? We expressed above our views: it should be clear, at least to a good extent, that science education will really bring contributions to indigenous children, so as to play a part in turning them equal in the face of a difference that makes them inferior, as Sousa Santos argues, and providing them with the skills, attitudes, and knowledge needed to function within their community cultures, within the mainstream culture, and within and across other ethnic cultures, as Banks proposes. These potential contributions should be discussed with the indigenous communities' leaders, so that they can have information to ground their decision to include or not science education in their schools. As Brayboy and Castagno recommend, it is fundamental to seek advice from tribal leaders, elders and other community members. It is also important to involve local people in the development of curricular materials, textbooks, etc. And, obviously, if science education is to be included in Indigenous schools, it should be part of a culturally sensitive and responsive educational process. It is not only a case of deciding what to teach Indigenous students, but, quite importantly, also how. The idea is not to force upon students the adoption of any particular way of knowing or body of knowledge, but to expose them to multiple worldviews so as to encourage them to acquire the skills needed to better serve their communities, and, also, to effectively compete in the dominant society if they choose this path. To both serve their communities and successfully enter the dominant society, it is likely that they will need not only to understand their own cultural heritage, but also mainstream Western culture, highly influenced by science and technology, and to move with no trouble between these two cultural settings.

Second, we cannot take as a goal that indigenous students do not suffer any change in their views through science education. Culture is dynamic and there is nothing intrinsically wrong with cultural change. Culture is no museum piece. We should worry that science education may subvert a range of social institutions and beliefs, given the strong relationships between knowledge and ways of living in traditional communities. But we should not adopt a paternalist attitude by thinking that traditional cultures are so feeble that their members cannot make intelligent and sensible decisions about what accommodations to make and not to make in the face of Western scientific knowledge. Any indigenous culture will necessarily change, through science education and through several different processes. The problem lies, rather, in situations in which cultures change in a manner that makes them lose their identity, i.e., when they undergo cultural erosion.

We should also consider that individuals necessarily change when they are educated. If this does not happen, what education would be for? An educational process that does not change the individuals engaged in it is simply useless. With regard to the problem at stake here, if indigenous students suffer no change through science education, this education will satisfy neither the general goals of multicultural education, nor the desires of indigenous communities that led them to decide that science education should take place in their youth's schooling process. It is evidently difficult to carry out any educational process in a multicultural setting without having as a result an excessive change in culture, or, ultimately, even cultural erosion. Nevertheless, this is the challenge to be faced and we believe it can be successfully met if, on the one hand, science education is culturally responsive and sensitive, and, on the other hand, indigenous students also undergo a vigorous process of education about their own cultural heritage. A contextual approach to science education can be also helpful, particularly if a comparative approach to different ways of knowing plays a part in the classroom, provided that the goal of science education, which we take to be understanding of scientific ideas, is not lost from sight. Furthermore, it should be clear that a science education aiming at understanding as a goal does not—or, at least, should not—operate under an assumption rightly criticized by Brayboy and Castagno, namely that all students must adopt the perspective of scientists. After all, it does not take belief change as a goal. It aims, rather, at promoting an understanding of scientific ideas. Even though this is certainly a difficult task, it also aims at border crossing into the culture of science without leading to the mere assimilation of students into that culture. This is not only a way of empowering students, but also of making science itself more vigorous, since it entails a recognition of both the possibilities and limits of science, giving room to other ways of knowing, so that science is not imposed by force, but can come to play a role in students' lives through dialoguing with their own perspectives. In this process, it is a key issue to distinguish between different ways of knowing, and, also, different domains of application, as even a multicultural thinker who is more radical than we, such as Snively (1990), recognizes to be an important goal. After all, he not only claims that it is possible to teach scientific concepts to Indigenous students without replacing their traditional spiritual view of the world or changing students' culturally grounded beliefs and values, but also that in this manner a teacher can increase a student's scientific knowledge so that it can be employed in the appropriate situations. It is our contention here that these goals are more likely to be reached if we do not simply mix together different ways of knowing so that they lose their identity, and, instead of a plurality, we have in the end just a mishmash.

Communicational approaches and understanding as a goal in instructional MSE

Dialogic approaches play a key role in a culturally sensitive science classroom, since they offer an opportunity for students to express their views in an inviting, rich atmosphere. It will also allow teachers and students to discuss how the diverse views represented in the classroom relate to scientific knowledge. In this manner, bridges can be built between students' cultures and the scientific culture. Brayboy and Castagno are quite right about the requisites for a teacher to engage in this kind of teaching. She should have an epistemologically well founded view about science and other ways of knowing, so as to address the relationships between them without assuming and conveying an idea of superiority of the former over the latter. She ought to realize that, when doing or teaching science, or any other way of knowing, one is always proceeding according to particular sets of assumptions. It is also important that the teacher is aware that, if science education does not address the social, political, and economic contexts in which scientific research and technological applications are developed, it will tend to reinforce inequities in the access of distinct social groups to scientific and technological developments. As educators, we should indeed put into question typical assumptions about who benefits and who suffers from scientific and technological development.

The goal of a dialogical approach in the science classroom should be to explore similarities and differences between ways of knowing; to stimulate students to consider how they are grounded on different ontological and epistemological assumptions, and, thus, it is not really surprising that they generate different discourses about the world; to offer opportunities to think about the domains in which one or the other way of knowing can be fruitfully applied; to consider the social, political, and economic backgrounds of the construction of scientific knowledge and technological developments; and, finally, to ponder about the nature of knowledge as a given set of arguments about the world that are supported by reasons, which we should reflect upon so as to accept or not a given idea. Thus, teachers can use—as Brayboy and Castagno propose—the epistemological stances to which students are committed as a resource to teach science more effectively, and, we should add, also in culturally sensitive terms.

Ethnobiological and ethnoecological knowledge, in particular, can play a central role in culturally responsive and sensitive science education for indigenous students. Indian children's experience (and, we add, knowledge itself) with issues such as soil erosion, conservation, management of ecological processes, knowledge of nature in general, technologies enabling survival, even in difficult ecological conditions, etc., can fruitfully interact with teaching about ecology, geology, pedology, and so forth. In a research conducted in our group, which dealt with traditional farmers' knowledge, we discussed the absence of their knowledge about plants in Botany lessons in a typical rural high school classroom in Brazil, something that is quite hard to understand (Baptista and El-Hani 2006). We related that absence with students' lack of motivation to learn science and feelings that scientific knowledge was not really useful, since they could see no connection between it—even when we are talking about plants!—and their own experiences and lives. Certainly, scientific knowledge could be richer, more authentic, and useful for those students if science teachers managed to connect it with students' knowledge and experiences as farmers. With this idea in mind, we developed a didactic material and teaching sequence aiming at giving room to farmer students' knowledge in the science classroom. But, when we implemented our proposal in a rural high school science classroom, we faced important limitations related to the lack of openness and sensibility to cultural differences by students themselves and, most importantly, to teacher education (Baptista and El-Hani 2007). We wholeheartedly agree with Brayboy and Castagno that "in order for teachers to engage in culturally responsive science education for Indigenous youth, they need a particular set of knowledge that they do not currently receive in teacher training programs." As the example we chose above shows, we want to add that this is true not only in the case of indigenous schooling, but when we deal with science education in traditional communities in general. We also agree with Brayboy and Castagno's selection of topics in which teachers need more knowledge, the nature of science, epistemology, and knowledge and cultural competence within traditional communities.

It is important to consider that, through instructional MSE, students may be able to understand why they reject a given scientific idea, if they do not accept it after being taught about it. They may reject a scientific conception, since, in our view, it is not for changing beliefs that the teacher is interacting with the students, but, if they still reject that conception, they now know why they take that position. They have become reflexive, critical, rational about what they think about the world. What more should we ask for, as science teachers? Should we ask them to believe in science? We do not think this should be our goal. We should be teachers, not preachers. And, as teachers, we should act, as Brayboy and Castagno remind us, as "cultural brokers," identifying students' cultural backgrounds, introducing WMS as a part of the Western culture, which may be, for many students, another culture, and making it clear all the time in the classroom within which culture we are operating, so that the demarcation between distinct cultures, with their own ways of knowing and bodies of knowledge, is systematically preserved in the science classroom, but with no denial of the value of any culture.

Moreover, if a teacher takes understanding, not belief change, to be the goal of her teaching, it is more likely that students successfully manage the necessity of broader crossings to the culture of science or, as Brayboy and Castagno write, the "conceptual interference" resulting from distinct knowledge systems, ways of knowing, and epistemologies (or, for that matter, metaphysics). Therefore, to take understanding as a goal can give us important tools to deal with the hazardous border crossings that the differences between WMS and Indigenous cultures may create for Native students. This is one of the reasons why we think that to take understanding as a central goal of science teaching is a key issue in the construction of a culturally sensitive science education, which may diminish cognitive conflicts arising from cross-cultural experiences in science learning.

Our favorite example to illustrate what we mean is the case of a biology teacher trying to teach evolution for a creationist student. In the beginning, the student just refuses evolution, but does not show any clear understanding of what scientific ideas about evolution do mean. The teacher does her best for the student to reach an understanding of current evolutionary knowledge, and, indeed, when she looks at the students' exams, classroom discourse, and so on, she can see indications that the student now came to understanding evolution to a significant extent. Then, in the last class, the student comes to the teacher and says, "Now, I understand what evolution is about, but I still do not believe it." As teachers, we would be satisfied with this result, we would not see it as a failure. Now, it is more likely that the student knows why she refuses to believe in evolution, it is likely that she pondered about the arguments and evidences for evolution, and came to see why they do not seem as convincing to her as they do for her teacher, for instance. At first, she did not believe in evolution by probably appealing to authority arguments, because her parents, a priest, her friends, etc., told her not to believe. Now, she moved to a more critical and reflexive appraisal of her own reasons to disbelieve in some ideas, and to believe in others. She not only succeeded in understanding science, but also reached a more sophisticated state in her own way of conceiving knowledge. She may now be able to understand why ideas in which she does not believe can be worthy of belief for other people. The teacher has succeeded in teaching for tolerance, coexistence with difference, even for rationality, in the sense of a commitment to critically appraise the reasons that can justify an idea.

It is true that one can say that, if belief change does not happen, why one should speak about learning at all (cf. Hoffmann 2007). Teaching for understanding can lead, in our view, to true learning, because, first, understanding typically yields belief, and, second, when it does not, quite important reasons are probably blocking the way, and these reasons quite often have to do with clashes between what we are asking students to believe in, and key ideas in their worldviews. In these cases, it is just good that understanding does not lead to belief. That is, most of the time a teacher who really wants students to use science in their daily lives will get satisfied with the fact that understanding leads them to belief, and belief may lead to action (provided that many potentially intervening factors does not hinder the translation of belief into practice). But there will be cases in which understanding must suffice to the teacher, since to ask for more is to enter into an avenue in which it will be difficult to keep respect for the students' culturally-grounded ideas that are at odds with scientific conceptions. The basic idea is that teachers should never try to directly shape students' ideas and, rather, teach for understanding, but, in many occasions, when it is legitimate, worthwhile, appropriate, understanding will naturally lead to belief.

It is a basic theme in this commentary, thus, that a major goal of science education is to promote understanding of scientific ideas. This claim leads us to consider that dialogic approaches are not enough in instructional MSE, despite their quite important role, as noted above. As Mortimer and Scott (2003) argue, dialogic approaches do not ensure meaningful learning. It is necessary that teachers also engage in authoritative discourse in order to systematize scientific knowledge, so as to make it understandable, learnable for students. Given the complex, rather abstract nature of scientific bodies of knowledge, it is just too much to expect from students that they get at a sufficiently systematized understanding of scientific concepts, models, theories by themselves. It is necessary that the teacher contributes to structure these bodies of knowledge, and to do so, authoritative discourse is particularly powerful. But, to avoid misunderstandings of what we are claiming, it is important to say what we mean by "dialogic" and "authoritative" discourses.

To understand the distinction between these kinds of discourse, we can take as a basis Bakhtin's (2000) distinction between *authoritative* and *internally persuasive* discourses. As Mortimer and Machado (2000) observe, "in an authoritative discourse, the utterances and their meanings are presupposed to be fixed, not modifiable, as they come into contact with new voices" (p. 434). An internally persuasive discourse, in contrast, is marked by "counter-words," as a result of a negotiation of meanings with the discourse of others. Therefore, it is highly dialogic. From these explanations, one can understand why science teaching should allow a progressive shifting between an authoritative, more closed discourse, and a dialogic, internally persuasive, open discourse.

A possible way of organizing discursive interactions in an instructional multicultural science classroom would be as follows: first, the teacher stimulates the students to engage in dialogic interactions, giving room to all voices in the classroom, encouraging a multi-voiced environment; then, after discussing students' ideas that appear in these interactions, not superficially, but trying to meet the goals of such a dialogue, the teacher may move to an authoritative, univoiced discourse, in which she is trying to systematize scientific knowledge, and, thus, intends to show the meaning of scientific statements in a more stable way, that is, as currently accepted by the scientific community of her time; and, then, the teacher can move again to dialogic interactions, since students will need to modify the scientific discourse in accordance with their own ideas to truly understand and apply it. As Scott et al. (2006) argue, "both dialogicity and authoritativeness contain the seed of their opposite pole in the dimension, and in this way we see the dimension as tensioned and dialectic, rather than as being an exclusive dichotomy" (p. 623).

Bakhtin's dialogic conception of language is one of the theoretical bases that can give support to this way of understanding "understanding." From this perspective, understanding necessarily involves a negotiation of meanings between different voices. Understanding is interpreted, from a Bakhtinian perspective, as a process in which a given person's utterances enter into contact with and confront another person's utterances. Thus, in response to the words of the utterance she is in process of understanding, a person formulates her own answering words, formulating a reply (Bakhtin/Volochinov [1929]1992). From this perspective, an indication that another person's discourse was understood by a given subject is the presence of 'counter-words' in her utterances. Students should populate the scientific discourse with their own words in order to understand it, and, through understanding, they will indeed modify the meaning of scientific ideas. This is unavoidable, the meaning of scientific ideas cannot be fixed anymore. If they do, we will not have meaningful, but just rote learning. In the process of learning, taken as understanding scientific ideas, the meaning of these ideas will be open to be modified by coming into contact with new voices, such as those present in the students' cultural grounds.

We offered a rather schematic description of shifts between dialogic/multivoiced and authoritative/univoiced discourses in classroom interactions. We urge our readers to not be deceived by this simplification. There is no reason why just three shifts should take place in a classroom. In the middle of a univoiced discourse by her teacher, a student may pose a question that leads again to dialogic interactions, and so forth. There are many possible ways of moving through these shifts in the complex environment of classrooms. Be that as it may, we think that in such an instructional MSE approach, a teacher can build a classroom practice that incorporates and values diversity, and, at the same time, does not lose from sight the goal of students' understanding of scientific ideas.

We cannot end this commentary without coming back to a question posed by El-Hani and Mortimer (2007, p. 683): how could we justify that science education, among all formative processes in a person's life, should exclusively accept the responsibility of giving access to a diversity of perspectives? We think that simply comparing different ways of knowing in the science classroom, without having as a goal that students understand scientific ideas and, above all, science as a mode of knowledge production, is to neglect the very reasons why students and teachers gather in the science classroom, with the purpose of understanding a specific way of knowing and the bodies of knowledge resulting from it. This is the reason why we defended not only understanding as the goal of science teaching, but also the role of an authoritative discourse when science teachers systematize scientific knowledge. All this should be done always taking into account students' worldviews, affective and motivational responses, potential conflictive feelings, etc. We do not disagree with the idea that schooling should give access to a diversity of perspectives about the world, not only for Indigenous, but to all students. What we argue for is that school as a whole should have this goal, not only science education, in particular. To learn about what constitutes reality for various cultural groups, as Brayboy and Castagno advocate, is, in our view, a goal for the school as a whole, as well as to establish communication between and among competing perspectives, and understanding of multiple and competing worldviews and epistemologies. But, to establish such a communication, one has, first, to master, to understand the perspectives themselves. To talk about a given perspective, and even to disagree about a certain idea, we have, first, to think about the same statement, and also to understand it. If one of the speakers does not understand what the other is talking about, there is no possible true conversation.

If an Indigenous student is to understand WMS and acquire an enlarged repertoire in the language of science, as it seems necessary to many traditional communities, she will have to be educated about WMS, she must understand it, although she does not need to believe in it. In this manner, it will be also easier to establish a positive attitude towards WMS, although it is also necessary to show the limits of this way of knowing, as well as its possibilities, and to critically appraise it in connection with social, cultural, economic issues. In turn, a positive attitude about their own way of knowing should be fostered both by a dialogic approach in the science classroom, which gives room to students' culturally-grounded perspectives, and by a vigorous education about their own cultural heritage in the schooling process as a whole. The best way of encouraging the student to reach these end results is to keep in mind the goal of promoting understanding of scientific ideas in the science classroom, not simply mixing up different perspectives in this setting. Moving between worldviews can really create high-level thinkers, as Fleer (1997) argues, but only if the distinct worldviews are not simply mixed up in a general hodgepodge. Distinguishing between worldviews is fundamental, as we argued throughout this commentary, and to do so, one should teach about a given perspective (be it science or not) for the purpose of systematizing it. Despite all the conversations we should have in the classroom about competing worldviews and epistemologies, there should be a moment in which teachers move towards a more authoritative mode of discourse, trying to systematize a given way of knowing. In a culturally sensitive school, diversity is to be built through systematizing not only one perspective, but several different perspectives about the world in different classes, and making room for dialogic interactions in which different perspectives are represented before and after authoritative modes of discourse.

As Brayboy and Castagno argue, both scholars and tribal community members share the goal of creating students with stronger critical thinking skills. Our argument here can be taken as meaning that this will be more likely if we educate them not to be (radical) relativists, but to be pluralists. It is quite a challenge, we concede, to build a multicultural science education that can meet all these goals. But would it be of any help to lessen the demands of the problem of educating people about science in multicultural settings?

In sum, we agree with most of the arguments put forward by Brayboy and Castagno in their paper, but we do think that it will be more helpful in building a culturally responsive schooling for Indigenous youth to maintain the standard explanation of the term "science" as referring to WMS, instead of broadening this concept so as to include in its meaning a whole series of human practices of knowledge construction. This is not necessary to fight scientism or to value Indigenous and traditional knowledge, and, in the end, may cause more harm and confusions than really advancing our comprehension of the diversity of knowledge systems, ways of knowing, and epistemologies. Just as a final note, it can be taken as further evidence in support of our arguments that, as Brayboy and Castagno mention, there is no word in traditional North-American languages that can be translated to mean science as defined by the Western culture. This is quite revealing and, in our view, shows how important it is to keep the distinctions in place when teaching and learning about science and indigenous ways of knowing.

References

Bakhtin, M. (Volochinov, V. N.) ([1929]1992). *Marxismo e filosofia da linguagem*. São Paulo: Hucitec.

Bakhtin, M. (2000). *Estética da criação verbal* (3rd ed.). São Paulo: Martins Fontes.

Bandeira, F. P., Castro, M., Chaves, M. J., Colaço, M., de Dantas, M. F., Almeida, T., Moura, L., & Modercín, I. (2007). O Povo Pankararé. In J. Marques (Org.). *As caatingas: Debates sobre a ecor-região do Raso da Catarina* (pp. 126–150). Paulo Afonso: Secretaria de Meio Ambiente e Recursos Hídricos do Estado da Bahia, Fonte Viva.

Bandeira, F. P. S., Chaves, J. M., & Lobão, J. S. B. (2005). An analysis of the indigenous ecosystem management strategies of Caatinga in the Raso da Catarina, Bahia, Brazil. In *Proceedings Annual Meeting of the Association for Tropical Biology and Conservation*. Uberlândia-MG: UFU.

Bandeira, F. P., Toledo, V. M., & López-Blanco, J. (2002). Tzotzil Maya ethnoecology: Landscape perception and management as a basis for coffee agroforest design. *Journal of Ethnobiology, 22*, 247–272.

Banks, J. A. (2008). *An introduction to multicultural education* (4th ed.). Boston: Pearson Education.

Baptista, G. S. C., & El-Hani, C. N. (2006). Investigação etnobiológica e ensino de biologia: Uma experiência de inclusão do conhecimento de alunos agricultores na sala de aula de Biologia. In P. M. M. Teixeira (Org.). *Ensino de ciências: Pesquisas e reflexões* (pp. 84–96). Ribeirão Preto: Holos.

Baptista, G. C., & El-Hani, C. N. (2007). Ethnobiology and dialogue between ways of knowing in biology teaching: A case study in a Brazilian public high school. *Science & Education* (Submitted).

Bauer, H. H. (1994). *Scientific literacy and the myth of the scientific method*. Chicago: University of Illinois Press.

Brayboy, B. M. J., & Castagno, A. E. (2008). How might Native science inform "informal science learning"? *Cultural Studies of Science Education*. doi:10.1007/s11422-008-9125-x.

Cobern, W. W., & Aikenhead, G. S. (1998). Cultural aspects of learning science. In B. J. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 39–52). Dordrecht: Kluwer Academic Publishers.

Cobern, W. W., & Loving, C. C. (2001). Defining "science" in a multicultural world: Implications for science education. *Science Education, 85*, 50–67. doi:10.1002/1098-237X(200101)85:1<50::AID-SCE5>3.0.CO;2-G.

Deloria, V. (1992). Relativity, relatedness, and reality. *Winds of Change*, Autumn, 35–40.

El-Hani, C. N., & Mortimer, E. F. (2007). Multicultural education, pragmatism, and the goals of science teaching. *Cultural Studies of Science Education, 2*, 657–687. doi:10.1007/s11422-007-9064-y.

El-Hani, C. N., & Pihlström, S. (2002). A pragmatic realist view of emergence. *Manuscrito, XXV*, 105–154.

Fleer, M. (1997). Science, technology, and culture: Supporting multiple worldviews in curriculum design. *Australian Science Teachers' Journal, 43*, 13–18.

Fordham, S. (1988). Racelessness as a factor in Black students' school success: Pragmatic strategy or pyrrhic victory? *Harvard Educational Review, 58*, 54–84.

Greene, J. C. (1981). *Science, ideology, and world view*. Bekerley: University of California Press.

Hacking, I. (1983). *Representing and intervening*. Cambridge: Cambridge University Press.

Hoffmann, M. H. G. (2007). Learning without belief-change? *Cultural Studies of Science Education, 2*, 688–694.

Kawagley, A. (1990). Yup'ik ways of knowing. *Canadian Journal of Native Education, 17*, 5–17.

Kuhn, T. S. (1977). Objectivity, value judgment, and theory choice. In *The essential tension* (pp. 320–339). Chicago: The University of Chicago Press.

Maffi, L. (1998). Domesticated land, warm and cold: Linguistic and historical evidence on Tenejapa Tzeltal Maya ethnoecology. In T. L. Gragson & B. G. Blount (Eds.), *Ethnoecology: Knowledge, sources and rights* (pp. 41–56). Athens: The University of Georgia Press.

Mahner, M., & Bunge, M. (1996). Is religious education compatible with science education? *Science & Education, 5*, 91–99. doi:10.1007/BF00428611.

Martin, K. (1995). The foundational values of cultural learning: The Akhkwasahsne science and math pilot project. *Winds of Change, 10*, 50–55.

Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science*. New York: Routledge.

Mortimer, E. F. (2000). *Linguagem e formação de conceitos no ensino de ciências*. Belo Horizonte: Editora UFMG.

Mortimer, E. F., & Machado, A. H. (2000). Anomalies and conflicts in classroom discourse. *Science Education, 84*, 429–444. doi:10.1002/1098-237X(200007)84:4<429::AID-SCE1>3.0.CO;2-#.

Mortimer, E. F., & Scott, P. H. (2003). *Meaning making in secondary science classrooms*. Maidenhead: Open University Press.

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*, 583–593. doi: 10.1002/sce.3730790507.

Pomeroy, D. (1992). Science accross cultures: Building bridges between traditional Western and Alaskan native cultures. In S. Hills (Ed.), *History and philosophy of science in science education* (Vol. 2, pp. 257–268). Kingston, ON: Queen's University.

Santos, B. S. (2001). As tensões da modernidade. In *Fórum Social Mundial, Biblioteca das Alternativas*. Available at http://www.forumsocialmundial.org.br, accessed at April 15th 2008.

Scott, P. H., 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*, 605–631. doi:10.1002/sce.20131.

Shrader-Frechette, K., & McCoy, E. D. (1994). Applied ecology and the logic of case studies. *Philosophy of Science, 61*, 228–249. doi:10.1086/289797.

Siegel, H. (1997). Science education: Multicultural and universal. *Interchange, 28*, 97–108. doi: 10.1023/A:1007314420384.

Snively, G. (1990). Traditional native Indian beliefs, cultural values, and science instruction. *Canadian Journal of Native Education, 17*, 44–59.

Snively, G., & Corsiglia, J. (2001). Rediscovering indigenous science: Implications for science education. *Science Education, 85*, 6–34. doi:10.1002/1098-237X(200101)85:1<6::AID-SCE3>3.0.CO;2-R.

Southerland, S. A. (2000). Epistemic universalism and the shortcomings of curricular multicultural science education. *Science & Education, 9*, 289–307. doi:10.1023/A:1008676109903.

Wittgenstein, L. (1969). *On certainty*. Oxford: Blackwell.

Charbel Niño El-Hani is professor of history, philosophy, and biology teaching at the institute of biology, Universidade Federal da Bahia, Brazil, and Researcher of CNPq (National Council for Scientific and Technological Development). He is affiliated with the Graduate Studies Programs in History, Philosophy, and Science Teaching (Universidade Federal da Bahia and Universidade Estadual de Feira de Santana) and in Ecology and Biomonitoring (Universidade Federal da Bahia). His research interests are in science education research, philosophy of biology, biosemiotics, theoretical biology, and animal behavior. His recent publications include "Towards a multi-level approach to the emergence of meaning processes in living systems," in Acta Biotheoretica (2006), in collaboration with João Queiroz; "A semiotic analysis of the genetic information system (2006), in Semiotica in collaboration with João Queiroz and Claus Emmeche; "Semiosis as an emergent process" (2006), in Transactions of the Charles Sanders Peirce Society, in collaboration with João Queiroz; and "Multicultural Education, Pragmatism, and the Goals of Science Teaching," in Cultural Studies of Science Education (2007), in collaboration with Eduardo Mortimer. He is a member of editorial boards of Brazilian and international journals in science education and philosophy of science.

Fábio Pedro Souza de Ferreira Bandeira is professor of ethnobiology and biodiversity conservation and management in the department of biology, Universidade Estadual de Feira de Santana, Brazil. He is affiliated with the Graduate Studies Programs in Botany and Environmental Modeling (Universidade Estadual de Feira de Santana). His research interests are in ethnobiology, ethnoecology and science education, applied and landscape ecology research and immaterial patrimony. His recent publications include

"Floristic heterogeneity in rustic coffee plantations, and its role in the conservation of plant diversity. A case study of the Chinantec region of Oaxaca, Mexico", in Biodiversity and Conservation (2005), in collaboration with Javier Caballero and Carlos Martorel; "A review about ethnomycology in Brazil and its contribution to the comparative ethnomycological investigation in Latin America", in Revista Mexicana de Micologia (2003), in collaboration with Aristóteles Góes Neto; "Tzotzil Maya ethnoecology: Landscape perception and management as a basis for coffee agroforest design", in Journal of Ethnobiology (2002), in collaboration with Victor Toledo and Jorge Lopez Blanco.