Cult Stud of Sci Educ (2007) 2:657–702
DOI 10.1007/s11422-007-9064-y

Multicultural education, pragmatism, and the goals of science teaching

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Received: 20 June 2007 / Accepted: 20 June 2007 / Published online: 9 September 2007

Abstract In this paper, we offer an intermediate position in the multiculturalism/universalism debate, drawing upon Cobern and Loving's epistemological pluralism, pragmatist philosophies, Southerland's defense of instructional multicultural science education, and the conceptual profile model. An important element in this position is the proposal that understanding is the proper goal of science education. Our commitment to this proposal is explained in terms of a defense of an ethics of coexistence for dealing with cultural differences, according to which social argumentative processes—including those in science education—should be marked by dialogue and confrontation of arguments in the search of possible solutions, and an effort to (co-)live with differences if a negotiated solution is not reached. To understand the discourses at stake is, in our view, a key requirement for the coexistence of arguments and discourses, and the science classroom is the privileged space for promoting an understanding of the scientific discourse in particular. We argue for "inclusion" of students' culturally grounded ideas in science education, but in a sense that avoids curricular multicultural science education, and, thus, any attempt to broaden the definition of "science" so that ideas from other ways of knowing might be simply treated as science contents. Science teachers should always take in due account the diversity of students' worldviews, giving them room in argumentative processes in science classrooms, but should never lose from sight the necessity of stimulating students to understand scientific ideas. This view is grounded on a distinction between the goals of science education and the nature of science instruction, and demands a discussion about how learning is to take place in culturally sensitive science education, and about communicative approaches that might be more productive in science classrooms organized as

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we propose here. We employ the conceptual profile model to address both issues. We expect this paper can contribute to the elaboration of an instructional multicultural science education approach that eliminates the forced choice between the goals of promoting students' understanding of scientific ideas and of empowering students through education.

Keywords Multiculturalism · Conceptual profile · Pluralism · Pragmatism · Science education · Goals

Introduction

Should a science teacher aim at promoting students' belief in or understanding of scientific theories and models? Some authors claim that the goal of science education should be a change in students' beliefs (e.g., Alters 1997; Lawson and Weser 1990). Similarly, Posner et al.'s (1982) conceptual change model focused on the replacement of a person's previous conceptions that played an organizing role in her conceptual ecology by another set of concepts, incompatible with the former. Other authors argue that science education should aim at students' *understanding* of scientific theories, models, concepts (e.g., Cobern 1996; Smith and Siegel 2004).[1]

In this paper, we side with the latter authors and expand on the idea that understanding should be the goal of a culturally sensitive science education within the context of a broader debate on multicultural education and of our own ideas about learning.[2] Debates about the goals of science education find a natural place in controversies about multicultural education. Thus, we first examine the tension between multiculturalism and universalism in the field of science education, as well as a recent tendency to find compromises between those two positions. We particularly focus on Cobern and Loving's (2001) defense of epistemological pluralism, arguing that it is in agreement with a general philosophical position, namely, pragmatic pluralism. The distinction between instructional and curricular multicultural science education (MSE) will play a key role in our treatment of epistemological pluralism. We then discuss how cultural pluralism can be understood in terms of a *plurality of reasons*, in accordance with Chaïm Perelman's theory of argumentation, and argue that cultural differences can be treated in three different contexts, related to conflict, consensus, and coexistence. We advocate here an ethics of *coexistence* in social argumentative processes—including those that take place in the context of science education— which demand dialogue and confrontation of arguments in the search of possible (but not inevitable) solutions, and an effort to (co-)live with differences if a negotiated solution is not reached. Among the conditions for coexistence of diverse

[1] Researchers who claim that understanding is the proper goal of science education do not agree in all respects. For instance, while Cobern (2000) argues against the distinction between knowledge and belief, particularly in the context of science education, Smith and Siegel (2004) advocates a clear distinction between these two constructs. Therefore, they see the primary goal of science education as being student *knowledge and understanding*. From his point of view, Cobern cannot accept that a science teacher should aim at understanding and knowledge, since for him knowledge and belief should be conflated, as he insists in his reply to Smith and Siegel (Cobern 2004). This debate raises quite general and complex topics: the search for criteria to distinguish between knowledge and belief is one the central problems in the theory of knowledge. Consequently, we cannot address this issue here and should leave it to future works.

[2] It is important to say some words from the very start about how we understand "culture". Even though we cannot expand on the issue here, we follow Geertz (1973) in his understanding of culture as "an ordered system of meaning and symbols, in terms of which social interaction takes place."

arguments and discourses, we will focus on the requirement of *understanding* each coexisting discourse as a basis for our commitment to understanding as the proper goal of science education.

Cobern's (1996) distinction between "apprehension" and "comprehension" and Wertsch's (1998) demarcation of "mastery" and "appropriation" is instrumental for our argument that even though a successful science student should not necessarily appropriate scientific ideas, she will necessarily have to understand or master them. The next step, then, is to be clear about what understanding means, and, in order to accomplish this, we characterize understanding in terms of four conditions: connectedness, sense-making, application, and justification. The criteria of application, in particular, brings the problem that if a student considers an idea false, even though she makes sense of it, it is clear that she will not tend to apply it. In this case, might we simply say that she did not understand the idea, even though the other three criteria were fulfilled? The criteria of application makes it explicit a central dilemma to science teaching focused on understanding: how can we avoid demanding that our students change their beliefs by learning science, and, yet, intend that they apply in their lives what they learn in the science classroom, a basic goal for virtually all science teachers? We propose a way out of this dilemma by addressing how understanding typically leads to belief and in which circumstances the latter is not a likely outcome of the former. Moreover, we discuss how the conceptual profile model, as a way of conceiving of science learning, also helps solving that dilemma. This model shows how the application of scientific ideas in the appropriate contexts is more likely when science teaching not only enriches with scientific ideas the range of views available for students to explain the world, but also clearly delimits their domain of application and raises students' awareness of both the diversity of human discourses about nature and the demarcation between them.

After addressing a way of treating learning in a culturally sensitive science teaching from the standpoint of the conceptual profile notion, we explain how instructional MSE built on the grounds of epistemological pluralism and the conceptual profile model eliminates a forced choice between the goals of promoting students' understanding of scientific ideas—even if they are committed to non-scientific worldviews—and of empowering students through education. Finally, we reach our proposal about how students' ideas (no matter if they are compatible with the scientific discourse or not) should be included in science education. In our view, 'inclusion' should be conceived as a demand for taking in due account the diversity of students' worldviews and giving them room in argumentative processes in science classrooms. This view is grounded on a distinction between *the goals of science education* and *the nature of science instruction*, from which we advocate that culturally sensitive science education should make room for dialogic approaches, allowing students' ideas to play a key role in discursive interactions in the classroom, but should also not lose from sight the goal of students' understanding of science and the need to engage also, in specific moments of the pedagogical practice, in authoritative discourse.

Multiculturalism, universalism, and epistemological pluralism

Since the 1990s, the relationships between culture and scientific education have been the subject of more and more critical appraisal. This tendency can be tentatively attributed to a number of factors (Cobern and Loving 2001; El-Hani and Sepulveda 2006): (1) the rise of constructivism as a strong tendency in science education; (2) a change in curriculum studies, which have become more focused on the historical processes of curriculum building; (3) a more critical attitude of several social and cultural groups towards Western Modern Science (WMS); and (4) the critique of the Western attitude toward other ways of knowing by research programs such as the Edinburgh program for the social study of science (e.g., Bloor and Barnes 1996), post-modernism (e.g., Lyotard 1995), and multi-culturalism.[3] All these factors had a deep impact on educational research and practice, and stimulated science educators to pose new and difficult questions about science teaching: Whose culture are we teaching when we teach science?; What criteria should we use to decide what counts and what does not count as science?; Is science universal?

The controversy about epistemological universalism and multiculturalism, which involves not only moral and political positions, but also philosophical stances about the epistemological status of WMS and other ways of knowing, has been so polarized that generated a lot of heat, but very little light (Southerland 2000). Recently, we can witness a movement away from extreme positions that casts a new light over the central issues at stake. Siegel (2002), for instance, argues that there is more common ground between universalists and multiculturalists than is usually recognized. It is instructive, however, to begin by illustrating this debate in black and white, although it ultimately came to involve different tones of gray.

Epistemological universalists such as Williams (1994), Matthews (1994), and Siegel (1997) advocate that science is, both as an activity and a body of knowledge, universal in character and cannot be taught in multicultural terms. In their view, respect for cultural diversity cannot have as a consequence the inclusion of other ways of knowing in science teaching. Matthews (1994) claims that the truth-finding goal of science transcends cultural influences due to the particular feature that the natural world acts as the final arbiter of scientific statements. This would explain the superior epistemic power of WMS in comparison with other ways of knowing.[4] As Matthews (1994) summarizes:

> The core universalist idea is that the material world ultimately judges the adequacy of our accounts of it. Scientists propose, but ultimately, after debate, negotiation and all the rest, it is the world that disposes (p. 182).

He illustrates this idea by presenting an often discussed example, namely that the science of lava flows is the same to people from the most diverse cultural, ethnic, religious backgrounds, just as volcanic eruptions are indifferent to their diversity. His conclusion, then, is that "For the universalist, our science of volcanoes is assuredly a human

[3] We use in this paper the term "multiculturalism" and related expressions that are typically used in the science education literature. Nevertheless, as Lopes (1999) discusses, it is not the case that terms such as "multiculturalism", "interculturalism", and expressions like "cultural plurality" and "cultural diversity" always share the same meaning, even though it is possible to find a common theme among them.

[4] Matthews (1994, p. 193) claims, for instance, that mainstream science may not provide complete answers, but it gives better answers than others. Siegel (2002) also seems to ascribe greater epistemic power to WMS, as the following statement indicates: "… universalists also believe that, from among the variety of possible ways of understanding the world, WMS is the most successful way of understanding it extant, when success is measured in terms of the production of the testable, predictive, and explanatory theories which mark science at its best" (p. 807). Notice that the latter part of his statement enunciates criteria for appraising knowledge which are proper of the scientific endeavor itself. This is clearly stated in a later section of the same paper (p. 809), entitled "WMS is scientifically superior to 'ethnic science'", where he argues that traditional ecological knowledge fails to satisfy "the criteria of good science to which WMS aspires". This shows how Cobern and Loving (2001) are right when they argue that to broaden the concept of science in order to embrace other ways of knowing can be a strategy that leads in the end to a devaluation of the latter (see below). But, to be fair, we should mention that Siegel also argues against denying the value of other ways of knowing.

construction with negotiated rules of evidence and justification, but it is the behavior of volcanoes that finally judges the adequacy of our vulcanology, not the reverse" (Matthews 1994, p. 182).

Matthews acknowledges the influence of sociocultural context on science, but immediately discounts any influence it might have on the truth of scientific statements, by claiming that cultural considerations do not determine the truth claims of science. It is clear, however, that the claim that an aspect of the natural world, such as the behavior of volcanoes, can judge the adequacy of our theories and models is far from being philosophically uncontroversial. Many arguments can be built against this claim, for instance, taking as a basis the Duhem-Quine thesis that scientific statements are always underdetermined by data (see, e.g., Cobern and Loving 2001). In fact, this idea has been used by diverse thinkers, such as Sandra Harding, Baas von Fraassen, Mary Hesse, David Bloor, Arthur Fine, Helen Longino, Thomas Kuhn, and Richard Rorty, to build arguments about the limitations of empirical evidence and scientific methods as constraints on our acceptance and rejection of theories (Curd and Cover 1998).[5] This shows how epistemological debates about universalism and multiculturalism weave an entangled web that may make us drift away from the goal of developing proposals for teaching science in multicultural settings in a respectful, sensitive, and efficacious way.

Therefore, maybe there is a point in Siegel's (1997) argument that the best way to understand and defend multiculturalism is not in epistemic, but in moral terms. He claims that science educators should embrace both a universalist view of multiculturalism (in moral terms) and a universalist view of science (on epistemological grounds). In his view, in order to respect the beliefs and ideas of other cultures, we do not need to treat those ideas as if they were correct, or at least as correct as the ideas built by WMS (Siegel 1997). Siegel intended to diminish the tension between multicultural education and epistemological universalism, but his arguments ended up being also polemical. Even though they may seem illuminating and liberating for some (e.g., Southerland 2000), they did not seem capable of attracting the sympathy of multiculturalists (see, e.g., Stanley and Brickhouse 2001, and Siegel's reply in his (2002)).

Multiculturalists such as Hodson (1993), Ogawa (1995), Kawagley et al. (1998), and Snively and Corsiglia (2001) claim that the universalist position, as a dominant feature of current science education curriculum, not only supports an exclusion policy, but is also incorrect from philosophical, moral, and political perspectives. They argue for the inclusion of other ways of knowing in the science curriculum, and often (but not always) assume an epistemological relativist position. One of their basic strategies is to broaden the

[5] There is a lot of debate about the underdetermination thesis, as we can see, for instance, in two papers collected in Curd and Cover's volume on philosophy of science, Gillies (1993/1998) and Laudan (1990/1998), as well as in the organizers' commentaries themselves. Our intention here is not to advocate that underdetermination and, by implication, theory-ladenness of observation entail that Matthews is wrong. We want to make a weaker point, which is enough to our purposes here: both underdetermination and theory-ladenness of observation show that Matthews' argument is controversial, not a statement one can really accept at face value. It is true that, as Siegel (2002) reminds us, universalists do not propose that WMS enjoys "unmediated access" to reality (contra Stanley and Brickhouse 2001), but rather accept that "… our scientific investigations of the natural world, although 'mediated' by our cultural/historical/gendered/class/etc. locations and associated conceptual schemes, can yield genuine knowledge of that world" (Siegel 2002, p. 806). It is clear, then, that universalists like Matthews and Siegel acknowledge both underdetermination and theory-ladenness of observation. The polemics should hinge, then, on how one can accept these two theses and, yet, claim that the natural world can judge the adequacy of our theories and models. We think this is a way of putting the problem that is not a mischaracterization (cf. Siegel 2002), but does justice to universalist positions.

concept of science. Hodson (1993), for instance, criticized science curricula for harboring the implicit message that the only science is WMS, in his argument for a science education which does not do violence to the beliefs of students who do not share the worldview and conceptual framework of WMS. Williams (1994) reacted to Hodson's proposal, claiming that to include cultural beliefs and experiences under the rubric of science would actually do violence to science, as a universal endeavor. It is recognized by universalists, however, that Hodson developed a convincing argument about how Western science education can harm students with other cultural backgrounds, by being insensitive to issues of language, teaching, and learning styles (e.g., Siegel 1997).

Not all multiculturalists are relativists, but it is indeed common among them the view that WMS is just one example of a number of equally valid sciences built by mankind throughout its history. Ogawa's (1995) multiscience perspective and Kawagley et al.'s (1998) claim that science has a plurality of origins and a plurality of practices offer cases in point. From these perspectives, the treatment of other ways of knowing as sciences in their own right would better serve the needs of students with diverse cultural backgrounds and counterbalance the destructive effect of WMS over non-Western cultures. Moreover, this would be a way of taking in due account that WMS is not universal in the sense that it is undeniably a local product of European culture (even though it is itself the result of the convergence of several different cultural influences) that played a role in the expansionist movement of European countries since the 16th century.

After describing multiculturalist and universalist positions in their extreme versions, we will now focus on an interesting midway position found in Cobern and Loving's (2001) epistemological pluralism. They oppose the treatment of all ways of knowing as "science", as it follows, for instance, from the understanding of the term science as referring to any descriptive knowledge of nature developed through experience or simply as "a rational perceiving of reality" (Ogawa 1995, p. 588). The problem with this approach is that students may lose from sight, in the end, the differences between diverse ways of knowing. We also think it is better to reserve the term "science" for the way of knowing typical of Western modern societies, insisting on the legitimacy and usefulness of demarcating between different forms of knowledge, built in distinct sociocultural circumstances, even though demarcation can be "thorny" (Cobern 2004, p. 586). While trying to avoid neglecting the philosophical complexity of the problem, Cobern and Loving derive a Standard Account of Science from both a pragmatic view broadly accepted by the scientific community and critical areas of consensus about the nature of science identified by science educators.[6] By doing this, they do not intend to advocate that WMS possesses any sort of epistemic superiority. As they write, "being exclusive […] does not confer science with any privilege vis-à-vis other domains. Science is properly privileged only within its own domain for that is where its strength lies" (p. 65).

[6] We do not present their Standard Account of Science here, since it falls outside the main thrust of our argument. We refer interested readers to the original source. Notice, however, that it is important to recognize the diversity of views among philosophers of science, which may make it difficult to identify areas of consensus (e.g., Martin et al. 1990; Gil-Pérez 2001). Nevertheless, despite the inexistence of any single or consensual epistemological position and the undeniably complex, dynamic, and multifaceted character of scientific work, it is possible to propose a number of currently uncontroversial or less controversial features of the nature of science. Taken as a whole, they can be characterized as a general post-positivistic account of scientific practice and knowledge. A very interesting discussion concerning consensus views about the nature of science and corresponding deformed views about scientific work is found in Gil-Pérez et al. (2001).

In their view, the inclusion of other ways of knowing into a broad concept of science contributes to its devaluation, rather than its legitimacy. Indeed, to maintain a demarcation between science and other ways of knowing seems important for the sake of the latter themselves. To enlarge the reference of science in such a manner that any empirical descriptive knowledge of nature or rational perceiving of reality counts as science is a movement in which everyone loses: "Diversity is lost. Meaning is lost. Communication is lost" (Cobern and Loving 2001, p. 61). Other ways of knowing lose in this manner their distinctiveness as forms of thought. They are submitted to the criteria of WMS, and, consequently, not valued by their own merits, or, to be more precise, by validation criteria which are distinctive of the epistemic context in which traditional ecological knowledge (TEK) itself or, generally speaking, other ways of knowing are produced. They will be playing a game in which they are bound to lose, since they would have "to compete where WMS is strongest—technical precision control, creative genius, and explanatory power" (Cobern and Loving 2001, p. 62).

An important source of confusion in the multiculturalism debate is the conflation of universalism and scientism (Southerland 2000). The devaluation of other ways of knowing is not due to universalist views of science in themselves, or to the traditional account of what is science, but to scientism. By blatantly promoting the hegemony and superiority of science, scientism ends up lessening the value of other forms of knowledge. That WMS dominates at the domain in which it offers its most fruitful and efficacious outcomes, the 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.

It is fundamental to bear in mind that the scientific approach is not the best in all domains of human lives and activities. Therefore, it cannot dominate the public square as the only legitimate approach to build useful knowledge or the final authority for all cognitive statements. 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).

Poole (1996) offers an eloquent example of the limits of scientific explanation. He asks us to consider what a scientific study of a work of art, a picture, might inform us. It might give a chemical account of the pigments used in the picture, or a physical description of how it reflects the wavelengths of light, or a neuroscientific explanation of how our brain reacts to viewing it. It is evident that, no matter how fascinating they may be for their own sakes, these scientific accounts fall short of providing adequate answers to many issues which are of interest to a viewer or an artist, related to aesthetics, meaning, purpose, etc. Poole is not saying that pictures and our reactions to them cannot be described in terms of chemicals, wavelengths, or brain activities, but only that it is wrong to assert, in a scientistic manner, that these scientific accounts are the only valid ones. This is the same as ignoring each and every domain in which a scientific interpretation is not the best one. This goes far beyond accepting science as the best way of building an understanding of natural phenomena, into an undeniably political attempt to dominate the public square as the right answer for all human demands. Such a scientistic position denies the importance of other systems of thought, including art, literature, music, religion, TEK, which are very important, even fundamental for individuals in all cultures (Woolnough 1996). Consequently, it goes beyond the authority of science and, in our view, turns this otherwise fascinating human endeavor into a caricature of what it should properly be.

Scientific thinking has characteristics that make it uniquely useful, but also set limits as to what can be legitimately known through science (Southerland 2000). There are questions that science, as a way of studying the natural world, is not only unable to address, but even does not raise as problems for scientific investigation. It is just natural, then, that there are domains of human experience not amenable to scientific explanation, in which other ways of knowing can better serve the needs of human beings. This should not worry those who value science and wish to preserve the appreciation of its contributions to mankind (as ourselves), since the value of scientific thinking is preserved with regard to its own domain, despite the necessary recognition of its limits. But, to be fair, it is important in general terms to recognize the limits of all ways of knowing, not only science.

It is crucial to understand, thus, that universalism does not necessarily entail scientism. Siegel (2002), for instance, clearly recognizes the limits of scientific knowledge, despite his universalist credentials, when he writes that WMS does not always provide useful advice concerning practical problems, it is unfortunately subject to all manner of political and economic abuse, and it does not resolve fundamental questions of value. It is clear, however, that some additional qualifications are needed in universalism in order to avoid scientism. In particular, any claim of an overall epistemic superiority of WMS should be avoided, since it straightforwardly entails devaluation of other ways of knowing and it is in the end indistinguishable from scientism. The adequacy of epistemic criteria built by the scientific community to appraise scientific statements should not lead in any way to a denial of the importance of knowledge constructed outside this framework. Other ways of knowing rely on different criteria, according to which other statements are true and valid. It is in these terms that epistemological pluralism avoids scientism, recognizing the variety of ways of knowing as well the differences and disagreements they show with respect to what "truth" is. But, at least as articulated by Cobern and Loving (2001), it also rejects epistemological relativism, since it acknowledges the necessity of discriminating between competing claims. Cobern (2000) argues that relativism, conceived as a view according to which any claim can be equally true or equally false, is a source of cynicism. Comte-Sponville (2002) forcefully indicates the risks of relativism, when he claims (in a discussion about skepticism) that if nothing was neither false (as relativism suggests) nor true (as rampant skepticism says), there would be no difference between knowledge and ignorance, or between being honest and lying. If everything is a lie (or if everything is true), then everything is permitted. Cobern vigorously distinguishes pluralism from relativism, by claiming that pluralism does not entail that all members of the plurality are equal. It is not the case that "anything goes" in either science or science education (Cobern 2000).

Finally, to elaborate in a precise manner the implications of epistemological pluralism, it is worth considering a distinction between "instructional" and "curricular" multicultural science education (MSE) (Southerland 2000). The former focuses on the necessity of taking in due account students' worldviews in science classrooms, particularly when they differ from the scientific picture. What is at stake, then, is a proposal of teaching science as standardly defined, but in a manner that is sensitive and respectful to the diversity of worldviews and cultures in classrooms. Curricular MSE, in turn, advocates that the conception of science itself should be redefined so as to include under its umbrella ways of knowing other than WMS. These two stances lead to fundamentally different approaches to the goal of making science teaching culturally sensitive.

Epistemological pluralism entails a defense of instructional rather than curricular MSE. It proposes that science should be taught as standardly understood, but other ways of knowing should be sensitively addressed in the science classroom, without losing from sight either the goals of science education or the fact that different ways of knowing are distinct and (typically) largely independent discourses about nature. By defending instructional MSE while maintaining the Standard Account of Science, epistemological pluralism can be liberating, because it eliminates a forced choice between the goals of teaching scientific ideas to students of most cultures and of empowering students through education, as we discuss in the section "Instructional MSE and student empowerment".

Pragmatic pluralism

Cobern and Loving's views are in agreement with a general philosophical position, namely pragmatic pluralism. Despite the many varieties of pragmatist philosophy (see below), a basic common theme in the tradition of pragmatism is a strong emphasis on the practice- and discourse-embeddedness of any human cognitive construction (El-Hani and Pihlström 2002; Pihlström 1996),[7] including scientific theories, descriptions, explanations, and also any form of TEK, art, religion, etc. The vast majority of post-Kantian philosophers recognizes that any way of knowing works with representations that are necessarily shaped, in part, by concepts we, humans, bring to the task of describing and explaining the world. Thus, no simple mirroring relationship between theory and world ever obtains (Mitchell 2003; Pihlström 1996).

We should recognize from the beginning that universalists like Matthews (1994) and Siegel (1997) readily acknowledge such human-embeddedness of knowledge statements. The adequacy thesis, according to which the material world ultimately judges the adequacy of our accounts of it, cannot be equated to a commitment to a simple mirroring relationship between knowledge and reality. The difference should lie rather in the consequences one derives from that acknowledgment.

Pragmatists insist that it is meaningless to speak about the truth of theories and conceptualizations independently of their human and social embeddedness. Stanley and Brickhouse (2001) write that the knowledge provided by WMS (or, for that matter, any way of knowing), albeit quite reliable and effective, can never be said to be the same thing as reality, not even at the level of our most basic empirical knowledge. Nevertheless, a universalist like Siegel (2002) also declares his agreement with the thesis that knowledge statements built by WMS cannot be identified with reality. The controversy between multiculturalists and universalists does not seem to hinge on this point.

From a pragmatist standpoint, one advocates that the cognizable world and any explanation, description, observation we build about it are necessarily conceptualized through our practices of predication and inquiry (El-Hani and Pihlström 2002). Therefore, we cannot demonstrate the truth or falsity of our statements about the world by appealing to empirical data; rather, data are elements in our arguments for particular statements (see below), even though they are, to be sure, quite important and powerful. A particularly important criterion in the assessment of our ontological commitments, epistemological

[7] Pihlström (1996) offers an extensive review of pragmatic realist positions. A thoroughgoing historical account of pragmatism with a comprehensive bibliography is Thayer (1980). Regarding pragmatist works, one should consider both classical pragmatists such as Peirce (1931–35/1958, 1992/1998), James (1907/1975), and Dewey (1929/1960), and neopragmatists, such as Margolis (1995), Putnam (1990), among others. This paper offers just a general outline of the implications of pragmatism to the understanding of MSE and the goals of science education. Several topics, including the detailed treatment of different pragmatist accounts, will be addressed in future works.

assumptions, and bodies of knowledge themselves is their pragmatic efficacy, which, in the scientific case, relates to theory building, empirical testing, technological application, etc. Pragmatic efficacy should be interpreted, however, in broader terms, including various non-scientific pragmatic effects our commitments and knowledge may have. We are not claiming that pragmatic efficacy can or should be the only criterion for appraising cognitive constructs. There are other important criteria, such as the internal consistency of a body of knowledge, or reasons for knowledge claims other than pragmatic efficacy, such as their empirical and theoretical consistency.

Sandra Mitchell (2003) expresses this pragmatic standard in a clear manner:

> Representational forms and particular representations are simultaneously illuminating and limiting. They cannot perfectly represent their objects because they do not display *all* the features of the thing represented. Therefore, they must be judged, at least in part, in terms of their usefulness (p. 128. Emphasis in the original).

This pragmatist position has nothing to do with “anything goes” relativism. We can judge the pragmatic efficacy of different ideas and concepts for addressing concrete problems in specified circumstances, and they can also be challenged and critically assessed from the point of view of other frameworks. We can thus recognize the pragmatic efficacy of WMS in its own domain, namely the understanding of natural phenomena, and at the same time take into account its limits for addressing other domains of human problems.

From a pragmatist standpoint, the interesting question is not if a reality that is independent from the knowing mind exists. As Searle (1995) argues, even the most radical social constructivist should assume “a reality independent of all social constructions, because there has to be something for the constructions to be constructed of” (pp. 190–191). The most important issue concerns the relationship between reality and cognitive constructs: how does reality relate to our knowledge statements? It is our view that reality or, more specifically, evidence about it *cannot* determine the truth-value of knowledge statements. Nevertheless, it can and does *constrain* the truth-value of such statements. What we mean is that evidence cannot lead us to establish one single true statement about reality; evidence does not allow, too, that just any statement might be true. Knowledge is a social construction, but this construction operates within a limited territory, constrained by an independent reality.

A pragmatist approach to the issues involved in the multiculturalism debate certainly demands further elaboration. In particular, since there are many flavors of pragmatism, it is important to explore the potential contributions of different classical pragmatists, such as Peirce, James, Dewey, and Mead, and also of neopragmatists, such as Margolis, Putnam, and Rorty, to the treatment of MSE and the goals of science education. It is important to ask what would be the similarities and differences of positions about the nature and goals of science teaching stemming from distinct perspectives such as those of Peirce and James.

We can now come back to Matthews’ argument that an aspect of the natural world, such as the behavior of volcanoes, can judge the adequacy of our theories and models, i.e., that scientists propose, but the world disposes. From the perspective sketched above, it is not that the world simply disposes of what scientists propose, it is not that the world merely judges whether a given cognitive construct, say, a theory about volcanoes, is or is not adequate. Or, to put it differently, it is not that evidence can select among the diversity of cognitive constructs produced by our social practices of knowledge building a construct which is more adequate. Rather, evidence only constrains the range of possible cognitive constructs. The twist in the treatment of the relationship between evidence and theory, in contrast to what is suggested by the adequacy thesis, lies in the fact that evidence does not single out a unique construct as more adequate, but just confers an objective dimension to such a construct through a constraining influence which still allows for a plurality of different constructs. As we do not have any unmediated access to reality, evidence—which depends itself on human practices of investigation—can offer powerful bases for arguments for and against statements, but cannot demonstrate that a given statement is generally speaking the most adequate.

The plurality of reasons

Alice Lopes (1999) claims that cultural pluralism should be conceived in terms of a *plurality of reasons*. In our understanding, she suggests a way of explaining universalism, multiculturalism, and pluralism as three different conceptions about the plurality of reasons: first, a hierarchy of reasons can be built by defining a truth standard according to which all other forms of knowledge are judged. Even though not all universalist positions are properly described in these terms, it is easy to see that epistemological universalism is the position that comes closest to proposing such a hierarchy of reasons. The idea that WMS is epistemically superior in terms of criteria such as explanatory depth, predictive power, etc., can easily lead to the definition of such a single truth standard.

A second way of understanding the plurality of reasons is treating them as being equivalent from both epistemic and axiological perspectives. This is a relativist position, often found among multiculturalists, even though multiculturalism does not necessarily entail it.

Finally, one can deny that reasons can either be put into any *a priori* or absolute hierarchy, or treated as merely equivalent. This position is close to pragmatism as explained above. In this case, reasons are treated as being valid and applicable in historically defined contexts, in which they can be evaluated through criteria of validity and legitimacy that are proper of those contexts.

Lopes (1999) elaborates her understanding of the plurality of reasons by appealing to Chaïm Perelman's theory of argumentation. She follows Perelman (1989/2004) in his criticism of the limited concept of reason in hegemonic philosophical thinking, in the sense that reason ends up being reduced to experimental rationality, and rational proof, to mathematical, demonstrative, analytical proof. This view leads to monistic conceptions of reason, cashed out in absolutist, totalitarian terms. Perelman argues that it is necessary to give room to other forms of rationality, also legitimate, not limited to evidence and calculus, and present in the plurality of human cultures. In this connection, Perelman's distinction between *demonstration* and *argumentation* is particularly important. Demonstration takes as a starting point true or allegedly true premises in order to derive true or probable conclusions, deductively or inductively, respectively. Due to its nature, demonstrative proofs seem to be less dependent on social and historical circumstances. Argumentation, in turn, concerns the construction of discourses aiming at provoking or augmenting the adhesion of subjects to certain theses. In contrast with demonstration, social and historical embeddedness is a key feature of argumentative processes.[8]

[8] Perelman is not arguing that argumentation is not the domain of logic. Rather, his argument is that logic comprises demonstrative proof, on the one hand, and the use of arguments, on the other (Perelman 1989/2004, p. 315).

We can now return to our argument against the adequacy thesis. In our view, this thesis is quite close to a treatment of the relationship between evidence and scientific statements as being one of *demonstration*. Although evidence is a cogent and powerful reason for accepting scientific arguments, scientists do not and cannot demonstrate scientific statements by appealing to evidence. Empirical data are used not to demonstrate, but rather to *support arguments in science*, since evidence is itself a human construction, loaded with theoretical grounds, assumptions underlying gathering and treatment of data, knowledge used in building equipments, etc.

With regard to argumentative processes in the social arena, including those that take place within science and science education, it is never too much to remember that there are not only scientific arguments, reasons, and epistemic criteria. There is a plurality of rational beings in that arena, gathered in groups such as the scientific community, science educators, traditional communities, religious groups, etc., all addressing problems in varied ways. This allows us to conceive of a dialogue that confronts plural perspectives and discourses, different arguments and reasons for them (Perelman 1989/2004).

In the social arena of argumentative processes, the participants cannot and need not *believe in* all discourses, but they should *understand both the arguments and the reasons* supporting them. Otherwise, they will not be able to really take part in the debate in a reflective and critical manner, they will not contribute to the dialogue and confrontation of arguments that can eventually lead to a negotiated solution. As Perelman argues (1989/2004), any argumentation depends on the acceptance of a number of theses, which can stem from common sense, or a given scientific, philosophical, theological field. Understanding of these theses is a foundation for argumentation, a necessary condition for its efficacy, and one cannot simply dismiss such theses without proper justification. A true dialogue between distinct ways of knowing, or forms of knowledge, demands understanding of, and knowledge about, the premises, arguments, and reasons constitutive of all sides involved in it. If we consider science education, in particular, we can see it as a crucial formative process for subjects to understand the complex premises, arguments, and reasons found in science, and, thus, be capable of engaging in an effective dialogue with scientific knowledge—often a crucial aspect of their social lives—, even though a number of them may not believe in some scientific ideas.[9]

Lopes (1999) distinguishes between two ways of treating cultural differences, related either to a *context of conflicts*, demanding dialogue and confrontation between social groups for a possible (but not inevitable) solution, or to a *context of consensus*, which, in the utopia of overcoming conflicts without confrontation, ends up disguising the differences and aborting the dialogue that might lead to some solution. Even though we are in general agreement with her argument, we would like to add a third position, in which one strives for building an ethics of *coexistence* for social argumentative processes, which demands dialogue and confrontation of arguments in search of possible (but not inevitable) solutions, but stresses that, if a negotiated solution is not reached, the diverse social groups should strive for (co-)living with their differences. Certainly, this is an ethics that is urgently required in our current world, and education, including science teaching, should play an important part in educating people in this direction.

[9] The theory of argumentation is not alien to pragmatist philosophies. On the contrary, as Perelman (1989/2004) shows, although that theory was almost entirely neglected in post-Cartesian logic and philosophy, studies about rhetoric as a means of argumentation, persuasion, and presentation received more and more attention due to the influence of pragmatism, moral philosophy, and philosophy of language on current thinking.

We envision three conditions for coexistence of diverse arguments and discourses: (1) discourse *independence*, i.e., an avoidance of indiscriminate mixture of discourses, which will often lead to the building of arguments based on contradictory foundations;[10] (2) discourse *consistency*, i.e., an effort to keep our discourses/arguments logically consistent; and (3) *understanding* of the coexisting discourses. Accordingly, we advocate understanding as the proper goal of science education.

Understanding as the goal of science education

Cobern (1996) argued that, instead of expecting that students *apprehend* (i.e., accept as true or valid) scientific theories, concepts, and models, science teaching should give priority to the goal of making students *comprehend* them. He offered a considerably circular definition of "comprehension", stating that to comprehend a proposition is to gain an understanding of it. It is necessary to say more about what comprehension or understanding means, and we will turn to this task in the next section. Anyway, the most important part of his argument lies in the claim that understanding does not lead to apprehension, which amounts to a truth judgment about a proposition. There is a fundamental difference between *comprehension* (*understanding*) and *apprehension* (*belief*), and comprehension does not necessitate apprehension.

Wertsch (1998) introduces a similar distinction between *mastery* and *appropriation* to deal with the relationship between an agent and the cultural tools she employs in mediated action. He defines *mastery* as "knowing how" to use a mediational means with facility. Appropriation relates to the distinction established by Bakhtin between "one's own" and "another's" word. According to Bakhtin (1981), we encounter the words in language as another's words and they become one's own only when the speaker populates them with her own intention, her own accent, *appropriating* the words. As language is not a neutral medium that passes freely and easily into the private property of the speaker's intention, the notion of appropriation has the advantage to function dialectically with its counterpart: resistance. According to Wertsch (1998), in many instances higher degree of mastery are correlated with appropriation. However, some forms of learning or understanding are characterized by mastery, but not appropriation, of a cultural tool. He gives examples in which Estonian interviewees who lived during the Soviet era were first asked to provide the official Soviet version of how Estonia became part of the Soviet Union in 1940 and then asked to provide the unofficial Estonian version. The interviewees offered two entirely different versions. According to Wertsch (1998), the Estonians "made a clear distinction between knowing an official history and not believing it, on one hand, and knowing and believing an unofficial history, on the other" (p. 158). That is, they mastered the official history taught in schools, but managed to both master and appropriate an unofficial history through a variety of channels that operated in private spheres of discourse.

It is clear that a person can understand or master ideas in which she does not believe and thus she can use those ideas without appropriating them. A deeply religious science student is likely to disbelieve evolutionary theories, as long as they enter into conflict with her most fundamental beliefs, but, yet, she must be able to understand or master those theories,

[10] It is not that all conceivable syntheses of different discourses are impossible, but just that they should be always taken with a grain of salt, since they will often lead to inconsistent arguments. We argue against indiscriminate mixtures of discourses. One should be aware of differences between ways of knowing, bodies of knowledge, arguments, and reasons.

if she is to be a successful science student. After all, a strongly naturalistically minded person can read a religious text about the supernatural origins of the world and understand it, even though she does not accept it as valid or true.

We also find in the science education literature the notion of "acceptance" (Sinatra et al. 2003), which is, in our view, closely related to Cobern's apprehension or Wertsch's appropriation. This can be seen, for instance, in Sinatra and colleagues' (2003) statement that, in order to avoid the term "belief", they refer to "a learner's personal assessment of the validity of a construct as her acceptance of that construct" (p. 512).

It is true that many researchers and teachers see in the failure to accept a scientific construct an obstacle to understand it. Smith (1994), for instance, writes that a learner's rejection of evolutionary theory can prevent her from hearing what the teacher has to say about the subject. How could we avoid such an outcome while teaching about a scientific topic such as evolution with understanding or mastering (not apprehension or appropriation) as a goal? As we will develop later, a learner who does not believe in evolution may be stimulated to strive for understanding it (and, thus, hear what the teacher says) by means of a contextual approach to science teaching, which makes it explicit that the scientific discourse about nature has both its domains of application and its limits, and is grounded on metaphysical and epistemological assumptions the student may not share. The main issue is that the student should master evolutionary theory and also understand why it is worthy of belief, even though she does not believe in it. In this way, a learner's disbelief in evolution may not deny her ability to build a proper understanding of the topic.

The relationship between acceptance and understanding can also operate in the opposite direction, i.e., students cannot accept a theory unless they develop some understanding of it (Lawson and Worsnop 1992). Therefore, a student who does not share the cultural backgrounds of the scientific discourse can find herself in a rather difficult position to learn science, if, on the one hand, her disbelief in that discourse hampers her understanding of it, and, on the other, the lack of understanding impedes her acceptance. How can we avoid this short circuit?

Several studies indicate that the relationship between knowledge and acceptance can be rather complex (e.g., Demastes-Southerland et al. 1995; Sinatra et al. 2003). Sinatra et al mention a study by Dole et al. that found no relationship between students' stated belief in creationism and their ability to understand texts about evolution! As they argue, students may understand evolutionary theory without accepting its validity, or, alternatively, they may accept it based upon a poor understanding. The first argument opens up, in our view, the most fruitful way to promote understanding of evolution (and also other scientific constructs) among students whose worldviews are at odds with it. Understanding and acceptance (or appropriation) can be dissociated. A student can understand a scientific theory, but does not deem it believable. In this case, it is particularly important that she also understands the reasons why that theory is worthy of belief, i.e., she should be aware that she rejects a theory other people may believe in because she rejects those reasons.

Apprehension or appropriation is based on a preexisting structure of knowledge, and, ultimately, on the basic assumptions about the world held by the subject, i.e., on her worldview (Cobern 1996).[11] Therefore, when a new idea is to be learned, its relationships

[11] According to Kearney (1984), the worldview of an individual corresponds to a set of basic assumptions underlying her acts, thoughts, dispositions, judgments, etc. These assumptions are both ontological and epistemological, and constitute criteria for appraising the validity and truth of ideas.

with an individual's fundamental beliefs play a central role in determining the outcome of the learning process. The importance of students' worldviews to science learning has been emphasized by anthropological and sociocultural perspectives on science education (e.g., Aikenhead and Jegede 1999; Cobern 1991). When applied to science education, worldview theory brings to the forefront the idea that all students enter the classroom with a set of epistemological and ontological presuppositions, in the context of which scientific ideas should find a niche, in order to be meaningfully learnt. From this perspective, every science classroom is multicultural, no matter if we are talking about New York, Bombay, Copenhagen, Rio de Janeiro or a small village in the Amazon forest. Students who do not share the cultural backgrounds of the scientific discourse will always be present and typically prevail. Therefore, to teach science is always a way of conveying a culturally based discourse, and to learn science is always a process of cultural acquisition, i.e., enculturation (Cobern and Aikenhead 1998; Mortimer 2000). From this perspective, science teaching should be planned and developed in such a manner that the students' cultural backgrounds, the power relationships in the classroom, the prospects of negotiation between different discourses, etc. are all taken in due account (O'Loughlin 1992).

Students whose worldviews differ from a scientific picture of the world will face science education as an experience of learning a second culture. Thus, science learning will usually involve a process of crossing cultural barriers, and border crossing into the culture of science can be a difficult process for a number of students (e.g., Aikenhead 1996; Costa 1995). An emphasis on understanding as the goal of science education arguably contributes to make border crossing less difficult, and potentially more successful. In contrast, to assume change of beliefs as a goal favors an undesirable situation in which science remains "another world" for several students.

What does "understanding" mean?

Smith and Siegel (2004) bring an interesting contribution to the explanation of what understanding means. They first appeal to Gauld's (2001, cited by Smith and Siegel 2004) arguments that the understanding of some notion is made up of ideas linked together and the connections defining the relationships between those ideas, and, moreover, that to understand something is to "make sense" of it or attribute meaning to it. These claims lead to two criteria for understanding: *connectedness* and *sense-making*.

Smith and Siegel (2004) add two more criteria or necessary conditions for understanding: *application*, i.e., that to say that a person understands a concept or idea is to say that she can apply it appropriately in both academic and non-academic settings; and *justification*, i.e., that understanding must involve a coherent appraisal of at least some of the reasons that justify a claim, or, to put it differently, render the claim worthy of belief.

Some caveats should be in place with regard to these criteria. If we focus on what is understanding in the context of scientific practice, the criterion of justification as stated by Smith and Siegel may be too strong, at least in some cases involving a high degree of expertise and/or cross-disciplinary work. For instance, a physicist can understand quantum mechanics theory, even though she may not be able to offer a coherent appraisal of rather technical mathematical proofs of it. In this case, a less strict criterion may be needed, according to which one understands a concept or idea if one can *recognize* some appropriate reasons for it, even though it may be the case that currently one cannot coherently appraise them. It is fair to say, however, that in the context of science education Smith and Siegel walk on solid ground when they argue that it is important to stress justification as a requirement for understanding. It is highly consensual in the literature on science education that a key element in science learning is that students grasp the empirical and theoretical reasons supporting scientific statements, and appropriately evaluate the merits of those reasons.[12]

Additionally, a contextual approach to science teaching demands that understanding include more than justification, also encompassing a modest comprehension of historical, philosophical, and sociocultural dimensions of science (Matthews 1998).

As to sense-making, the connection with the idea of "plausibility" in conceptual change theory, suggested by Smith and Siegel, seems problematic. Strike and Posner (1985), for instance, argue that one will find plausible a view that is "consistent with one's current metaphysical beliefs and epistemological commitments, that is, one's fundamental assumptions" (p. 220). In this sense, however, understanding will ultimately come to depend on compatibility with students' beliefs, and, consequently, it would become ultimately impossible to distinguish understanding from belief (see also Davson-Galle 2004).

Davson-Galle (2004) offers a modified account of the criterion of application that clarifies a central problem, namely, that if a student considers an idea false, she will think of it as being without appropriate application (at least in any way that presupposes it being a true theory). He argues that understanding only demands application in a conditional sense, i.e., that the student must show the following capacity: were she to believe a given scientific theory (say, the Darwinian theory of evolution) to be true and were some sort of problem to face her, then she would be able to use that theory "appropriately" to solve it. It is clear, however, that in this case the student would be able to apply the theory only in academic settings, where this kind of conditional situation is more likely to be present. In daily life, she would rarely make use of the theory. At first, this is just natural, since she does not believe in it. But, at second thought, this poses a dilemma to science teaching focused on understanding: it may be the case that students will not bring to their lives what they learn in the science classroom, an outcome that most science teachers highly cherish. What can we say and do about it? We will come back to this dilemma soon.

With these added caveats, the four criteria presented by Smith and Siegel (2004)—*connectedness*, *sense-making*, *application*, and *justification*—allow us to be more precise about the claim that *understanding* is the primary goal of science education.[13]

In order to make it clear where the difference lies between understanding and belief, particularly with regard to the last two criteria, we will briefly summarize some basic distinctions. A student who understands an idea grasps the reasons why that idea is worthy of belief, but does not necessarily believe in those reasons. If she comes to believe in those reasons, then understanding will lead to belief. This usually but not always happens. A student who understands an idea has a clear conception of situations or contexts in which that idea might be applied, but she does not necessarily apply it. If she comes to apply that idea in a given circumstance she must believe that at least at that circumstance the idea is fruitful and plausible. Here we face the dilemma mentioned above and it is quite clear that something more must be said about the diversity of human discourses about the world and their domains of validity/application. We will move to these issues now, by discussing that

[12] Other worries about the way Smith and Siegel explain the criterion of justification are spelled out by Davson-Galle (2004). We refer the reader to his original work.

[13] It is clear that in this debate about the goals of science education, and also in this paper, the focus lies on conceptual contents. Concerning other kinds of contents, such as attitudinal or procedural, more items would have to be added to a list of goals of science education.

dilemma and how the conceptual profile model can help us conceive properly of application as a condition for understanding.

A dilemma for culturally sensitive science education

The thesis that understanding or mastery does not necessarily lead to apprehension or appropriation has two consequences: first, that understanding seems to be indeed a proper goal for culturally sensitive science education, since students may be able to understand scientific ideas without changing their beliefs. Second, there is the following troublesome consequence: are science teachers aiming at understanding really capable of making science become an authentic part of students' daily reasoning and practical life? The problem lies in the fact that understanding does not guarantee the acceptance of a proposition as valid or true, and we hardly tend to apply in our lives ideas we do not accept as such.[14] We can identify, thus, a basic dilemma for culturally sensitive science education: how can we avoid demanding that our students change their beliefs by learning science, and, yet, intend that they apply in their lives what they learn in the science classroom? Surely, we could give up the second intention. But then why should we bother about teaching science at all?

Smith and Siegel's (2004) argument that even though belief does not always follow understanding, *understanding typically yields belief and typically guides action* is remarkably consequential to this dilemma. Suppose, for instance, that we go to a rural area where people are affected by some infectious disease because they adopt some habits that a scientifically oriented person would avoid. There, we observe a dedicated science teacher striving for making her students learn some scientific ideas, expecting they accept those ideas as valid or true, and, therefore, act in such a manner that they change the habits conducive to disease. Following Smith and Siegel, if the teacher aims at student understanding of scientific ideas, this will be typically successful, and the change of habits she looks for is likely to take place. This is a first step to a way out of the dilemma: culturally sensitive approaches to science teaching will typically lead to an application of scientific ideas in the proper contexts by the students, even though a teacher does not aim at changing their beliefs.

Furthermore, application of scientific ideas in the appropriate contexts will become more likely if science teaching aims at not only enriching with scientific ideas the range of views available for students to explain the world, but also at clearly delimiting their domain of application and raising students' awareness of both the diversity of views at hand to comprehend a given phenomenon and the demarcation between them. We will justify this claim when discussing our views about learning, related to the conceptual profile model.

Anyway, there may be situations in which the teacher will not be successful in leading students to apply a scientific idea in their lives. It can be the case, for instance, that students in that rural area refuse to believe in the scientific ideas presented by the teacher, even though they understand them. Then, understanding will lead neither to belief nor to a change in their habits, and they will still tend to be affected by the infectious disease. Certainly, a number of different reasons might be adduced to explain such a finding, but a

[14] One may argue that there are circumstances in which a person applies in her life ideas she does not accept as valid or true. We concede that this can happen, but there is a clear tendency to apply in our lives ideas we think to be true or valid.

putative explanation is that there may be some clash between scientific ideas and fundamental assumptions in the students' worldviews.

Then, what the science teacher should do? She can still strive for promoting among students a recognition of the diversity of discourses about nature, and, consequently, for stimulating application of scientific ideas in that specific domain related to their habits conducive to disease, without affecting (if this is possible) fundamental ideas in their worldviews. But if this also fails, she may consider that, even though health is important, culture is also a key issue in students' lives. There are, after all, many accounts of the destructive influence of Western worldview over other cultures (Cobern and Loving 2001). This does not necessarily lead to a commitment to a relativistic perspective, or even to the idea that science education should be avoided in each and every traditional community (this is an issue we should address in a case-by-case basis), but it indeed shows that we should be careful while teaching science in multicultural settings, found in schools all over the world, including typical Western cities.

A proper goal to science education is to stimulate students to recognize the scientific status of the theories they are been taught (Smith and Siegel 2004). That is, instead of striving for making them believe in scientific theories, a science teacher should guide her efforts to promote a belief that those theories provide the *best current scientific account* of the relevant phenomena based on empirical and theoretical consistency. Nevertheless, students must judge for themselves the merits of scientific claims, and they have the basic right to refuse believing in them, even though they must understand they are the most accepted theories in the scientific domain.

A particularly important case arises when a student rejects scientific claims because she sticks to religious ideas in a fundamentalist manner. Southerland (2000), for instance, argues that in this case the teacher should help the student understand the religious grounds on which her belief is based, and point out what kinds of questions religious views answer and which they do not. The teacher will be working in dangerous but necessary territory, trying to stimulate students' understanding of the domains of application of different ways of knowing. An effort to demarcate the domain of science as a way of knowing is also necessary, so that students also understand what kinds of questions scientific knowledge cannot address. The student may never accept or believe in scientific explanations, but the science teacher would have played her role in an appropriate manner, promoting understanding of scientific explanations, the reasons for them, the process of their construction, and the demarcation of the domains in which they are adequate.

Conceptual profiles, discursive interactions, and culturally sensitive science teaching

How learning should be conceived in culturally sensitive science teaching? A key issue, as discussed above, is that from our point of view learning should not entail students' change of beliefs, but rather students' understanding of scientific ideas. If any change of belief happens, it should be just the typical (but not guaranteed) result of understanding, not of any attempt to directly shape the content of students' beliefs. Therefore, students should not be prompted to necessarily replace previous conceptions with an organizing role in their conceptual ecology by another set of conceptions incompatible with the former, as in the conceptual change model proposed by Posner et al. (1982). We advocate here that learning can be properly understood in the context of culturally sensitive science education in terms of Mortimer's model of conceptual profile change (Mortimer 1995). In particular, we claim that the conceptual profile model helps us comprehend how a student can come to apply a scientific idea she understands in some but not all contexts of her daily life.

The idea of a conceptual profile—that people can exhibit different ways of seeing and representing the world, which are used in different contexts—was proposed in the 1990s (Mortimer 1995), inspired by Bachelard's (1940/1968) epistemological profile, and its central argument that a single philosophical doctrine is insufficient to describe all the different forms of thinking that emerge when we try to understand a single concept. Each form of thinking constitutes a zone in an individual conceptual profile and has a different weight in that profile. The weight of each zone depends on the experience and opportunities the individual has to apply that zone in its appropriate contexts. For example, the empiricist notion of mass as something that can be determined with a scale has a bigger weight in a profile of a chemist who works daily in a chemical laboratory weighting samples than a rational notion of mass as a relationship between force and acceleration that she learned at school. The opposite holds true for a physics teacher that teaches Newton's law every year to several classes. In this sense, each individual has a different conceptual profile for each concept, with more or less different zones and different weights for each zone, depending on her everyday, school, and work experiences.

The idea of a conceptual profile was first proposed as an alternative to conceptual change (Posner et al. 1982) and is aligned with criticisms we find in other tendencies, such as Cobern's contextual constructivism, for instance (Cobern 1996; El-Hani and Bizzo 2002). It is an attempt to frame the problem of generating new meanings in science teaching considering the interplay between modes of thinking and ways of speaking. The basic assumption is that different modes of thinking that characterize the heterogeneity of thinking are interwoven with different ways of speaking, which allows for the study of the different zones that constitute a profile through the study of the different discourses and practices that characterize each of these ways.

Heterogeneity of thinking means that in any culture and in any individual there exists not one, homogeneous form of thinking, but different types of verbal thinking (Tulviste 1991). This general idea can be also found in other formulations, for example, in the "tool kit" analogy used by Wittgenstein (1953/1979) for characterizing his language games. It expresses, also, an acknowledgement that word meanings are essentially polysemous.

The notion of heterogeneity despite genetic hierarchy, discussed by Wertsch (1991), assumes that different forms of thinking can be ranked genetically (in the sense of development or generation), but the latter forms are not assumed to be more powerful. Based on the notion of "spheres of life" mentioned by William James (1907/1975) in his description of where common sense, science, and critical philosophy may be adequate and appropriate, and on the "activity-oriented" approach outlined by Tulviste, Wertsch assumes that the development of new forms of activity gives rise to new types of thinking. Nevertheless, since the earlier forms of activity continue to fulfill some role in culture, the old types of thinking employed in these earlier forms are preserved and continue to function well in their appropriate contexts. According to Wertsch (1991), "this position […] can be summarized by saying that although some forms of functioning emerge later than others, they are not inherently better" (p. 97).

Assuming the existence of conceptual profiles as a manifestation of heterogeneity of thinking implies recognizing the coexistence in the individual of two or more meanings for the same word or concept, which are accessed and used in the appropriate contexts. Science itself is not a homogeneous form of knowing and speaking, and can provide multiple ways of seeing the world, which can exist together in the same individual, and be drawn upon in different contexts. For example, the concept of the atom is not restricted to one unique point of view. Chemists deal with the atom as a rigid and indivisible sphere, like the Daltonian atom, in explaining several properties of substances. The structural formulae used by chemists also represent the atoms arranged in molecules in this way. This model is not, however, suitable for explaining several phenomena, including, for example, chemical reactivity, where more sophisticated models, including those derived from quantum mechanics, are used.

According to the notion of conceptual profile, learning a concept involves two interwoven processes: enriching a conceptual profile and becoming aware of the multiplicity of meanings the profile harbors and the contexts in which they can be applied. In science teaching, the first process typically means to learn scientific zones the students generally do not have access to by other means. In the second process, it is necessary to give the students a clear view about which meanings are appropriate in which contexts. For example, a student can become aware that the scientific concept of “heat”, as a process of energy transfer between systems at different temperatures, is complementary to her everyday concept of heat, which assumes heat as being proportional to temperature: some likes it hot. If the notions are complementary, there are contexts in which one of the concepts is more appropriately used than the other. For example, to ask in a shop for a “warm woolen coat” is far more appropriate than asking for “a coat made from a good thermal insulator, which prevents the body from exchanging heat with the environment”. Furthermore, if we know that this “warmth” of the wool is in fact the warmth of our body as the wool only isolates it from the environment, we are demonstrating our conscious awareness of this profile, drawing on everyday and scientific ideas of heat in a complementary way.

Although each individual has her own conceptual profile for each concept—with a different number of zones and different weights of each zone—, sociocultural theory makes it possible to assume that the concepts and categories available in all the spheres of the world are held in an essentially similar form by a number of individuals inside the same culture, in a way that allows effective communication. These “collective representations” (Durkheim 1972) have a supra-individual characteristic and are imposed upon individual cognition. Vygotsky, drawing from this position (Kozulin 1990), pointed to the social dimension of the human mental process. According to his famous ‘general genetic law of cultural development’, “any function in the child’s cultural development appears twice, or on two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an interpsychological category, and then within the child as an intrapsychological category” (Vygotsky 1981, p. 163).

The Bakhtinian notions of speech genres and social languages can help us find ways to relate different zones of a conceptual profile with different ways of speaking. Talking about what he called the languages of heteroglossia, Bakhtin claims that a national language is not unique, but composed of several different social languages, which “are specific points of view on the world, forms for conceptualizing the world in words, specific world views, each characterized by its own objects, meanings and values. As such they all may be juxtaposed to one another, mutually supplement one another and co-exist in the consciousness of real people” (Bakhtin 1981, p. 292).

In addition, we should consider that to become aware of a multiplicity of meanings and contexts involves, in our terms, the dialogue between new and old zones in a conceptual profile. Any true understanding, or meaning making, is dialogic in nature because we lay down a set of our own answering words for each word of an utterance we are in the process of understanding (Voloshinov 1929/1973, p. 102).

Another interesting question to address is which sequences of communicative approaches, as described by Mortimer and Scott (2003) and Scott et al. (2006), would be more productive while engaging in a dialogic relationship with students committed to different worldviews and ways of knowing, provided that neither students nor teachers can forget that the main goal is to understand scientific ideas.

Dialogic approaches in the beginning of a teaching sequence offer the opportunity for students to express their views and then later to see how these views relate to a given scientific perspective. In addition, "dialogic engagement is potentially motivating of students, drawing them into the problem at hand and legitimizing their expression of whatever ways of talking and thinking they possess" (Scott et al. 2006, p. 622). At the same time, dialogic approaches should not be restricted to the initial exploration of students' conceptions. It is important that students have also the opportunity to explore newly learned scientific ideas for themselves through talk and other actions.

Nevertheless, dialogic approaches alone do not ensure meaningful learning (Mortimer and Scott 2003). Normal science (Kuhn 1970/1996) is played through authoritative discourse, which offers a structured view of the world. It is not possible to be introduced to the tools of scientific reasoning without guidance and assistance. The authority of scientific arguments helps to develop a high degree of intersubjectivity between different people sharing the same scientific paradigm. Thus, if meaningful learning involves making connections between ways of thinking and talking, science teaching should allow for a progressive shifting between authoritative and dialogic communicative approaches, with each giving rise to the other. As Scott et al. (2006) aptly remarked, "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). Thus in a teaching sequence it is possible to find moments when the teacher encourages dialogic discourse to make students' everyday views available, so as to help students become aware of them. The approach can be shifted to an authoritative one when she aims at introducing the scientific point of view. Then she prompts dialogic discourse as she encourages students to explore and apply the scientific view. Thus, the shifts in communicative approach continue throughout the teaching sequence.

Assuming the heterogeneity of language, meaning and thinking, and the dialogic nature of understanding and learning as theoretical principles that support conceptual profiles, we are in a position to define the basic tasks that should be carried out if we wish to understand how people learn scientific concepts and how these concepts can be taught in terms of conceptual profiles: (1) Determining the zones that constitute the conceptual profile for a number of central concepts; (2) Characterizing individual conceptual profiles by investigating how these zones are used in different contexts by individuals belonging to certain groups; and (3) Investigating the interplay between different ways of thinking and modes of speaking in the meaning making process in science classrooms.

We have been working on this research program investigating the first of these three tasks for three basic quite general definitions—matter (Mortimer 2000), energy (Amaral 2004), and life (Coutinho 2005), and the related concepts of particulate models of matter, atom, and molecule (Mortimer 1998, 2000; Mortimer and Amaral 1999); heat, entropy, and spontaneity of physical and chemical processes (Amaral and Mortimer 2004, 2006); life and living beings (Coutinho et al. 2007). We also worked on the second task for the concept of life and on the third task for the concepts of matter and energy. And, finally, we are now building a conceptual profile for the concept of adaptation (Sepulveda et al. 2006).

Given that nowadays there is almost a consensus around the idea that concepts are heterogeneous and that concept use is bound to contexts, what a research program on conceptual profiles can offer to the science education community? First, we do not have a theory of conceptual development or a theory of teaching scientific concepts that accounts for this heterogeneity. Theories of conceptual development tend to assume this process as an endeavor towards a rational, non-contradictory, and uniquely powerful scientific way of conceptualizing, which can allegedly subsume all the other forms, treated as "inferior". This characterization of conceptual development is, however, clearly at odds with the conception of culturally sensitive science education advocated here. By proposing a theory that holds multiplicity of meanings and dialogue as basic principles we try to position the science learner in a place much more coherent with her pluralist condition of belonging to different communities and dealing with different points of view, which constitutes the rule and not the exception in the lives of most students in the Western world.

Second, the conceptual profile research program tries to build on at least four traditions in the field of science education: the "alternative conceptions movement"; the scientific literacy movement; multiculturalism; and the "discursive turn" in science education, which emphasizes the role of language in science teaching and learning. In building this research program we try to re-estate the centrality of conceptual learning for the endeavor of teaching science, while recognizing, at the same time, the importance of culture, language, and context in this process. Even if science curricula nowadays tend to be built around thematic and contextual issues, learning scientific concepts is to be found amongst the aims of any curricular proposal in science education and is still at the core of the problematic nature of science teaching and learning.

In summary, the conceptual profile research program attempts to be responsive to all the main developments in the field of science education. In this sense, it also offers a model of research in science education to be discussed, criticized, and developed.

The conceptual profile notion helps answering the question of what kind of learning should be expected in a culturally sensitive science teaching. It preserves the idea that to develop a conceptual understanding in science, it is necessary to establish relationships between scientific and everyday meanings for the same words. But this relationship is not one of subsuming all other forms of knowledge into science, but rather of dialoguing between different forms of knowledge in order to clearly distinguish among them and among the contexts in which they can be better applied. In this sense, meanings other than the scientific ones that a word can acquire are not treated as "inferior", but as culturally adequate for the different spheres of life in which we act and talk. This does not mean that one should necessarily avoid being critical about commonsensical and other culturally based views, but rather that one is entitled to restrict the validity of these criticisms to the domain in which science is valid. In critiquing, for instance, a commonsensical view that heat is proportional to temperature and opposed to another form of heat, "cold", a teacher should insist that this latter view is different from the scientific one and far more convenient to speak about cold and hot things in everyday life, since it has a deep cultural root, is part of our language, and allows for communication in most everyday situations and activities.

Nevertheless, to deal with other everyday life situations, the scientific view of heat as a process of energy transfer is far more convenient than the commonsensical view of heat and cold as properties of materials. Consider, for example, a case in which one has to decide which type of glass is better to preserve the low temperature of a drink in a warm day, one made of aluminum or one made of glass. The commonsensical view would lead us to choose the aluminum, since it is "cold". The scientific view, instead, helps us understand that this coldness is due to the transfer of heat from the aluminum to the liquid, thus making the drink warmer. Since aluminum is a better thermal conductor than glass, the drink will get warmer quicker in the aluminum than in the glass.

It is in this sense that we claim that the conceptual profile model helps us comprehend how a student can come to apply a scientific idea she understands in some but not all contexts of her daily life. In the first case, to talk about warm clothes, the commonsensical view is far more convenient. In the second, to decide in which type of glass to drink a cold drink in a warm day, the scientific view is much more appropriate. If we help a student to become aware of her conceptual profile of heat and temperature after learning the scientific view, she can comprehend in which contexts of daily life she can apply this scientific view she came to understand.

Instructional MSE and student empowerment

There are a number of important political, moral, and social reasons for defending multicultural science education (MSE).[15] We take these reasons as grounds for a weaker version of MSE than many multiculturalists have advocated. As we hope the previous sections showed, we are committed to a version of instructional MSE grounded on epistemological pluralism and the conceptual profile model. In this section, we intend to explain how it eliminates the necessity of choosing between the goals of promoting students' understanding of scientific ideas and students' empowerment through education. By "empowerment", we mean in this context that science education should enrich the students' conceptual ecologies, by giving them access to scientific discourses about the world (broadening the range of discourses they can understand and potentially apply) and stimulating them to be more critical and reflective towards knowledge in general.

In most cases, not to teach WMS in a clear and well-demarcated way will harm students' development in their social environments, since it will alienate them from a quite powerful way of knowing and a crucial factor in cultural history in the last 400 years. Therefore, a rather cogent justification (usually related to the need of cultural preservation) should be offered to deny a social group access to scientific knowledge and the practices stemming from it.

A primary factor for achieving success in teaching science as traditionally defined and, yet, contribute to empower students is, in fact, to avoid taking change of belief as a goal of science education. We should focus, rather, on understanding of scientific ideas, which means that a student should grasp the connections between scientific concepts and statements; be able to make sense of them; be capable of applying them in the appropriate contexts, not only in academic settings; and properly appreciate what counts as good reasons in the domain of science. It is particularly important that the criterion of justification does not entail that students should believe in scientific ideas, but only that they should appreciate the reasons that make those ideas *worthy of belief*. In this way, science education can contribute to the important general goal of promoting tolerance, to the extent that it is successful in making students understand that ideas one does not believe in can be worthy of belief, and, thus, other people may legitimately believe in them. This would educate people for coexistence of a plurality of arguments and reasons, differently from

[15] In the Brazilian community of researchers on science education and curriculum studies, sociopolitical reasons for MSE are strongly advocated (e.g., Assis and Canen 2004; Candau 2002, among others). More effort should be directed towards a dialogue between curriculum studies and science education with regard to multicultural issues, and, in particular, political and social topics related to MSE.

epistemological absolutism, which can and often do promote intolerance. We certainly live in a world in need of tolerant people, and, consequently, this general goal of education is obviously of central importance in our times, torn by conflicts between different world-views and lacking proper grounds for negotiation, due to widespread fundamentalist, absolutist beliefs.

As Cobern (1996) argues, candidates for knowledge are judged on the grounds of our fundamental—typically intuitive, non-rational—beliefs. If we take understanding to be the proper goal of science education and consider the four criteria discussed above, we can come to the conclusion that in order to understand a scientific claim a student should go beyond an immediate judgment based on her intuitive beliefs, and appreciate at least some of the reasons that make it worthy of belief. In this manner, science education can promote rationality, since in order to effectively understand science one has to shift from a non-rational appraisal of claims about the world to a rational appraisal.

Arguably, we can foster application of scientific ideas in students' lives, going beyond the conditional manner suggested by Davson-Galle (2004), if we succeed as teachers in achieving three results: first, that students understand that there is not and should not be a single discourse about the world, but, rather, a plurality of discourses, for moral, social, political, and even aesthetic and adaptive reasons; second, that they understand that, even though there are no epistemically superior ways of knowing in absolute terms, we can judge the consequences and/or coherence of different ideas when applied to specific problems and contexts, and we can also critically assess them from the point of view of other frameworks; third, that they acquire a view as clear as possible about the different domains of application of different discourses, scientific, religious, political, everyday, etc., in the manner described in the conceptual profile model.

Curricular MSE has led to science curricula which are, in our view, entirely untenable. This happens with 'science' curricula in which only those aspects of WMS that are in agreement with ethnic science are taught. This is a misguided effort to strengthen and support students' cultural knowledge. An example critically appraised by Southerland (2000), and Cobern and Loving (2001), among others, is Adam's (1990) *African-American Baseline Essays*, a set of six essays published in 1987 by the Portland Oregon School District in order to provide materials for teachers about the knowledge and contributions of Africans and African-Americans. Hundreds of copies of these essays have been distributed in USA due to the pressure on school districts to incorporate multicultural material into the classroom. The problem with these essays lies in their use of a triumphalist approach as a way of raising the self-esteem of students, through which they present the achievements of several ethnic groups as being particularly advanced and anticipatory to the achievements of WMS. Cobern and Loving treat them as an example of "radical revisionist historiography of science and culture", which not only gets entangled in groundless statements, such as that Egyptians anticipated many of the philosophical aspects of quantum theory (Adams 1990), and knew the particle/wave nature of light (p. 26), but also inadvertently submits other ways of knowing to the standards of science, contributing to devaluing rather than to cherish them (Cobern and Loving 2001; Southerland 2000). After all, the grounds for treating the achievements of a given ethnic group as advanced lie in the assessment that they would have been anticipatory to accomplishments of WMS. This shows how curricular MSE may sometimes seem closer to scientism than one might think at first, despite its broadened definition of "science".

A much better way of empowering students in a culturally sensitive approach to science teaching is to *explicitly* address the historical, philosophical, and sociocultural dimensions of science. Instead of avoiding epistemological distinctions between different ways of knowing, we should teach students about the cultural background, epistemological assumptions, and methodological procedures of WMS, along with scientific concepts, theories, and models themselves.

The role of contextual science teaching in multicultural education can also be emphasized from the point of view of researches about the manner in which affective and intentional constructs, including epistemological commitments, affect students' understanding of controversial topics, such as biological evolution (e.g., Demastes-Southerland et al. 1995; Sinatra et al. 2003). Sinatra and colleagues (2003), for instance, show that students who see knowledge as tentative and subject to change—i.e., who are *not* epistemological absolutists—and have a disposition toward open-minded thinking are more likely to accept scientific explanations of controversial topics, such as human evolution. In the same study, they observe that lack of openness to changing one's beliefs may be a barrier to understand evolution. This raises another difficulty to understanding as a goal of science education. If the degree to which a student is disposed to hold on to or question her beliefs is strongly related to understanding of controversial topics, would it be the case that a teacher who does not focus on change of belief could fail, in the end, in promoting student understanding?

First of all, it is worth mentioning that this is more likely in evolution teaching than in many other topics in science education. Students who do not know about or disagree with the tentative nature of scientific knowledge may view evolutionary theories as far more tentative and controversial, and, thus, less valid than not so controversial topics. Furthermore, evolution is an inherently complex and difficult to learn topic, even when there is no conflict with students' views. In this case, dispositional factors tend to be more important (Sinatra et al. 2003). Second, a putative solution to this problem does not necessarily involve a commitment to change of belief as a goal of science teaching; rather, it may just involve contextual teaching. As Sinatra and colleagues argue, "… learners disposed toward open-mindedness—that is, students who are willing to analyze and question their beliefs intentionally, *even if they do not accept the validity of evolutionary theory*—can come to understand the content" (p. 522). Therefore, it may be possible to attain success in promoting students' understanding of evolution by stimulating them to be open-minded, and, particularly, to overcome absolutist views about knowledge (when they are committed to them), without trying to make them change their beliefs in the science classroom. An open-minded, non-absolutist student may be ready to comprehend why a given account is *worthy of belief*, even though she does not believe in it.

A contextual approach to science education can contribute both to lessen the emotional demands of science learning for students committed to culturally grounded ideas at odds with scientific claims and to foster students' disposition to open-mindedness. In particular, contextual science education can lead to a conception of science as a *powerful but bounded* human activity that provides important but not all answers to human pragmatic concerns. The differences between various systems of thought as well as their strengths and shortcomings in specific domains of human life should receive attention in science classrooms, particularly when addressing controversial topics such as evolution and the origins of the universe, life, human species, etc. When teaching about these topics, it is particularly important to address students' prior knowledge, since possible conflicts with their worldviews seem to be a major factor leading to learning difficulties by pupils who do not share the scientific view (e.g., Cobern 1996; Costa 1995). It is also important that students feel comfortable enough in the classroom to address points of conflict, interpretations about natural phenomena from their own cultural backgrounds, and questions about science, the procedures of scientific knowledge building, and the reasons for scientific statements.

Students with a more sophisticated understanding of the nature of science will be more likely to compare knowledge frameworks, and to understand how and why scientific knowledge is different from other knowledge systems. But they will also be more prone to appreciate the limits of science, and how they are related to its epistemological and ontological underpinnings.

There is, however, a potential tension between contextual approaches to science teaching and epistemological absolutist views. As Cobern (2000) argues, scientism allows a teacher to say the students that science simply tells us how things are. But when a teacher who possesses more knowledge about history and philosophy of science explicitly addresses metaphysical, epistemological, and methodological assumptions of science, and/or explicitly deals with the prospects and limits of scientific knowledge, it may be the case that a student committed to an epistemological absolutist view simply refuses to understand scientific ideas. After all, if she believes that a given knowledge system is absolutely true, why would she waste her time learning all that series of conjectural theories and hypotheses about nature?

In this case, we should take into account students' agency in the learning process, which should be always recognized (Southerland 2000), but certainly has a price. It is always possible that a pupil decides not to learn, not to understand scientific ideas. If the teacher made her best to promote science learning, what might she do if a student decided not to learn? A recognition of students' fundamental role as agents of learning brings with it not only the necessity of respecting them as active players in the classroom, but also of acknowledging their responsibilities: if a student decided not to learn, unless there is some clear reason in classroom practices and interactions that promoted that lack of interest, the student should be held responsible for her decision, not the teacher. Or, to put it differently, in a setting where everyone is an agent, one single agent cannot be responsible for everything that happens, particularly if we are talking about an internal decision of one of the players; rather, responsibility is shared among all the players.

A view about "inclusion" in science education

There is nothing to regret about the science classroom being a place of students' enculturation (Mortimer 2000) or border crossing into the culture of science (Aikenhead 1996; Cobern and Aikenhead 1998). After all, each and every way of knowing has its own places and modes of enculturation. The question is not one of denying the role of enculturation in science education, but, rather, of explicitly and critically acknowledging it and then addressing the problem of culturally sensitive science teaching.

Science teaching should be open to students' ideas (including non-scientific), but without losing from sight the goal of understanding scientific models, theories, and concepts. But if we advocate an argumentative process involving a diversity of discourses in the science classroom, would it not be the case of striving for inclusion of other ways of knowing in science education in the sense of curricular MSE?

To give a proper answer to this challenge, we should question what inclusion means. After all, very different proposals can be subsumed under the claim that other ways of knowing should be "included" in the science classroom.

First, we do not accept an equal time, equal emphases strategy in the science classroom because inclusion in this sense would mean losing from sight the goals of science education. If one believes that this would allow students to freely choose the explanation that looks more adequate to them, one is neglecting, first, that human beings do not come to education as free people who might choose one view by democratically having access to a range of different perspectives. We live in a diversity of cultural media, and, as we move through them, we face a variety of pressures, constraints, formative processes, etc.[16]

Second, how could we justify that science education, among all formative processes in a person's life, should exclusively accept the responsibility to give access to a diversity of perspectives? A possible argument is to stress the fact that science education is required of all students, particularly in countries that adopt "science for all" curricula. But does this really make science education more powerful than, say, religious education? Would it make sense to require, for instance, that protestant churches include a diversity of perspectives while teaching their pupils? We guess many, if not most people, will say that this does not make sense. But why does such a proposal sound unreasonable? We think reflection will show that this is the case because religious classes have a clear goal, to make people believe in the doctrines of a given religion. Science education, in turn, does not have (in our view) belief as a goal, but, yet, aims at understanding of scientific ideas, and not at offering an overview of the parade of knowledge systems created by human beings that are represented in a given society.

An "equal times/equal emphases" conception of inclusion neglects 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. 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.

Nevertheless, we can understand inclusion in a different, and arguably more productive manner, much in line with instructional MSE, epistemological pluralism, and the conceptual profile model. In this sense, inclusion means that we should take in due account the diversity of students' worldviews, and, if students bring non-scientific ideas to the discursive interactions in science classrooms, we should give room for them in the argumentative processes.

The crux of this argument is that one should distinguish between *the goals of science education* and *the nature of science instruction*. In culturally sensitive science education, teaching should take place in a significantly dialogic manner, allowing students to bring a diversity of ideas to the science classroom, but pedagogical work should be also organized in the direction of fulfilling the goal of students' understanding of science.

Concluding remarks

In this paper, we elaborate an intermediate position in the multiculturalism/universalism debate, which draws upon Cobern and Loving's (2001) epistemological pluralism, pragmatist philosophies, Southerland's (2000) defense of instructional MSE, and our own ideas on learning, developed in the conceptual profile model (Mortimer 1995). We advocate that students' understanding of scientific theories, models, and concepts is the proper goal of science education. We think that if science teaching adopts change of beliefs as a goal, it runs the risk of degenerating into nothing more than a proselytizing, indoctrinating, scientistic endeavor. The decision to believe or not in scientific ideas is up to the students, but

[16] Chalmers (1999) builds precisely this argument against Feyerabend's (1993) claims related to education.

they are necessarily entitled to understand those ideas, if they are to be successful science learners. A teacher is more likely to stimulate her students to be successful in this sense, and, yet, empower them if she gives significant room for their voices in discursive interactions in the science classroom, but does not lose from sight the goal of understanding science. The ideas presented in this paper should be seen as an attempt to contribute to the construction of a model of culturally sensitive education that can lead to this outcome, based on a clear distinction about the nature of science instruction (and the corresponding communicative approaches in the science classroom) and the goals of science education.

Acknowledgments: We are grateful to members of the Graduate Studies Program in History, Philosophy, and Science Teaching (Universidade Federal da Bahia/Universidade Estadual de Feira de Santana, Brazil), the Faculty of Education (Universidade Federal de Minas Gerais, Brazil) and the Center for Philosophy of Nature and Science Studies, at the University of Copenhagen, Denmark, for interesting discussions about the ideas presented here. Among them, we are particularly indebted to João Queiroz, Olival Freire Jr., Orlando Gomes de Aguiar, Marie Svarre Nielsen, and Claus Emmeche.

Contract grant sponsors: CNPq and FAPESB, Brazil.

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Learning without belief-change?[17,18]

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In "Multicultural education, pragmatism, and the goals of science teaching," Charbel Niño El-Hani and Eduardo Fleury Mortimer try to find their way between Scylla and Charybdis. Threatened, on the one hand, by a "scientistic" conception of science education that might "do violence to the beliefs of students who do not share the worldview and conceptual framework of WMS" (Western Modern Science) and, on the other hand, by a "curricular" understanding of multicultural science education that might "collapse into a mere confusion" since only those aspects of WMS are taught "that are in agreement with ethnic science," threatened by both these extremes they argue for an intermediate approach: "culturally sensitive science teaching." This middle way between a "scientism" that is driven by a claim for hegemony and superiority and a multicultural confusion which, at the end, devaluates anything that makes science worthwhile to study and to use, this middle way—called "instructional multicultural science education"—has many features nobody would refuse: taking into account the diversity of students' worldviews and sensitively addressing other ways of knowing; providing room for discussing non-scientific ideas in the science classroom; promoting tolerance; teaching in a dialogic manner; not "losing from sight the goal of understanding scientific models, theories, and concepts"; empowering students through enriching their "conceptual ecologies"; addressing the historical, philosophical, and sociocultural dimensions of science; fostering students' open-mindedness; and promoting rationality. These should obviously be central aspects of any kind of formal school education all over the globe.

Besides these unquestionable features of 'good teaching,' however, the authors' main point is the claim that multicultural science education should focus on "understanding" while avoiding to demand "that our students change their beliefs by learning science." The distinction between *understanding* and *belief change* is the central focus of El-Hani and Mortimer, and that is exactly the point I want to concentrate on in this discussion. The authors' position is best summarized in the following statement:

"A primary factor for achieving success in teaching science as traditionally defined and, yet, contribute to empower students is, in fact, to avoid taking change of belief as a goal of science education. We should focus, rather, on understanding of scientific ideas, which means that a student should grasp the connections between scientific concepts and statements; be able to make sense of them; be capable of applying them in the appropriate contexts, not only in academic settings; and properly appreciate what counts as good reasons in the domain of science. It is particularly important that the criterion of justification does not entail that students should believe in scientific ideas, but only that they should appreciate the reasons that make those ideas *worthy of belief*."

[17] This commentary should be cited as follows: Hoffmann, M. H. G. (2007). Learning without belief change? *Cultural Studies of Science Education, 2* (3), doi: 10.1007/s11422-007-9064-y.

[18] This contribution reacts to Charbel Niño El-Hani and Eduardo Fleury Mortimer's article "Multicultural education, pragmatism, and the goals of science teaching." Quotes refer to a version from March 2007.

In this quote, El-Hani and Mortimer use a helpful definition of what “understanding” means that is elaborated more extensively in other parts of the text. Based on work by Smith and Siegel (2004), they distinguish four different aspects that make up “the understanding of some notion”: (1) comprehending the *connectedness* of this notion within a network of ideas; (2) being able to *make sense* of this notion, what is defined here as attributing meaning to it; (3) being able to *apply* a concept or idea “appropriately in both academic and non-academic settings”; and (4) *justification*, i.e., “understanding must involve a coherent appraisal of at least some of the reasons that justify a claim, or, to put it differently, render the claim worthy of belief.”

While this provides a convincing understanding of the term “understanding,” the notion of “belief,” however, remains dangerously ambiguous throughout the text. In the beginning, they follow Posner et al. (1982) in defining changing belief as “conceptual change,” that is “the replacement of a person’s previous conceptions that played an organizing role in her conceptual ecology by another set of concepts, incompatible with the former.” But then they seem to associate “belief” rather with a “worldview” as provided by a certain culture, that is “the basic assumptions about the world held by the subject.” Then they link believing to accepting something “as true or valid.” In formulations like to “believe in scientific theories” again, the reader is reminded of something like religious faith. This understanding of “belief” is again emphasized when they talk about the goal of religious classes “to make people believe in the doctrines of a given religion.” Most clear becomes this direction of using “belief” when they conclude in the end: “We think that if science teaching adopts change of beliefs as a goal, it runs the risk of degenerating into nothing more than a proselytizing, indoctrinating, scientistic endeavor.” Since conceptual change—their initial definition of belief—is not necessarily connected with either accepting something as true or valid or believing “in” it without reason, the meaning of the concept seems to change imperceptibly over the course of the argument.

Nobody in academics, I guess, would subscribe to the idea that scientific knowledge is a question of faith. The focus is always on providing reasons, providing evidence, and on *arguing* for assumptions and hypotheses. That means, a science education that would try to change students’ faith, or what they believe in, by indoctrinating them would simply miss the point of science. There is no question that “belief change” in this sense of the term should be avoided. But what about “belief change” in the sense of conceptual change?

Although I do not think that “belief” can sufficiently be defined by reference to concepts alone, I do think that there is a sense of “belief change” that should never be neglected by science education. But let us start with the question of how “belief” can be defined. Considering the fact that we use the verb “believe”—besides in “believing in”—first of all in “believing *that*,” it should be clear that what we belief “in” are not concepts, or “conceptual ecologies,” but *propositions*. “I belief that the earth is a sphere” means that I am ready to accept the proposition—that is a statement that can be true or false—“the earth is a sphere.” A standard philosophical definition of “belief,” correspondingly, is the following:

“Contemporary analytic philosophers of mind generally use the term “belief” to refer to the attitude we have, roughly, whenever we take something to be the case or regard it as true. To believe something, in this sense, needn’t involve actively reflecting on it: Of the vast number of things ordinary adults believe, only a few can be at the fore of the mind at any single time. Nor does the term “belief”, in standard philosophical usage, imply any uncertainty or any extended reflection about the matter in question (as it sometimes does in ordinary English usage). Many of the things we believe, in the relevant sense, are quite mundane: that we have heads, that it’s the 21st century, that a coffee mug is on the desk.” (Schwitzgebel 2006)

Since Plato, the philosophical debate circles around the distinction between "belief" (or "opinion," in Greek *doxa*) and "knowledge" (*epistêmê*, Lat. *scientia*). While both are usually considered—within an epistemological context—to be representable in the form of propositions, the decisive difference between both concepts becomes clear when we take into account that Plato introduced the definition of "knowledge" as "true belief combined with justification" (*tên men meta logou alêtê doxa epistêmê einai*, Plato, *Tht.* 201c,d). Belief, according to this most influential starting point of what later has been called epistemology ("theory of knowledge"), is one of three *conditions* of knowledge, the other ones being that the belief in question must be true, and that it must be possible to provide reasons for it (see for an overview of the philosophical debate on belief Steup, 2006).

The consideration that belief is a necessary condition of knowledge should be important for a "culturally sensitive science education." Without *believing* that something is the case, there cannot be any *knowledge* that this is the case. The argument is simple: Knowing presupposes that there is, first, an *individual* who knows something and, second, that this individual is in a certain *cognitive state* of knowing, be it potentially or actually. The fulfillment of both these conditions in a certain situation is what is usually called "believing" in philosophy. The concept of "belief" is best defined, I would say, by these three points: it is (a) a cognitive state of an individual that (b) refers to something that can be represented in a proposition; and (c) this cognitive state consists in the disposition to accept—if asked—this proposition as being true.

Based on these considerations it does not make any sense to me to give up the goal of "belief change" in education. If we assume that the goal of education is learning, and if a central aspect of learning is the development of knowledge, and if developing knowledge means that we believe, at the end of this process, that something is the case that we did not believe to be the case in its beginning, then giving up the goal of belief change would lead to an education that says "Good bye" to the idea of learning.

Although El-Hani and Mortimer do talk about "learning" science, what remains when we take away belief change as defined above can hardly be called "learning." Based on their distinction between *understanding* and *belief change* they argue for the thesis that it should be sufficient that students can attribute meaning to what they hear in the classroom ("sensemaking"), that they can give "some" reasons for scientific claims, models, and theories ("justification"), that they know how to relate those scientific components to other parts of scientific knowledge ("connectedness"), and that they know how to apply it even if they never would apply it for themselves; but all this without believing that anything that is claimed in science is true, or should be accepted as true. "The decision to believe or not in scientific ideas is up to the students, but they are necessarily entitled to understand those ideas, if they are to be successful science learners."

What all this is about is a kind of fake-learning. As I argued above, the essential idea of believing as well as of knowing is that a person is in a certain cognitive state of accepting something as true. For El-Hani and Mortimer, however, it is sufficient that students can "handle" scientific knowledge without knowing it in this cognitive sense. They would be happy with a form of "knowing" that is possible—by contrast to the traditional understanding of "knowledge"—without an individual's personal, cognitive involvement.

"It is clear that a person can understand or master ideas in which she does not believe and thus she can use those ideas without appropriating them. A deeply religious science student is likely to disbelieve evolutionary theories, as long as they enter into conflict with her most fundamental beliefs, but, yet, she must be able to understand or master those theories, if she is to be a successful science student. After all, a strongly naturalistically minded person can read a religious text about the supernatural origins of the world and understand it, even though she does not accept it as valid or true."

Indeed, it is possible to "master" and "use" ideas without accepting them as true. But to what degree, and what are the costs? Besides the fact that a cognitive state in which a complete alienation between scientific ideas and a person's belief-value system is realized excludes the possibility of "learning"—as defined above—I would like to hint at another problematic implication of El-Hani and Mortimer's approach. This implication concerns the possibility to argue.

At one point, El-Hani and Mortimer talk about the fact that in the "social arena" all sorts of argumentative processes take place:

"There is a plurality of rational beings in that arena, gathered in groups such as the scientific community, science educators, traditional communities, religious groups, etc., all addressing problems in varied ways. This allows us to conceive of a dialogue that confronts plural perspectives and discourses, different arguments and reasons for them (…). In the social arena of argumentative processes, the participants cannot and need not *believe in* all discourses, but they should *understand both the arguments and the reasons* supporting them. Otherwise, they will not be able to really take part in the debate in a reflective and critical manner, they will not contribute to the dialogue and confrontation of arguments that can eventually lead to a negotiated solution."

Enabling students to participate in debates and deliberative processes should indeed be a central goal of any education. In order to resolve conflicts, to participate in decision-making and collaboration, and to solve problems, students must be able to argue. The possibility to argue, however, depends on certain conditions. Those conditions have been most thoroughly studied by Jürgen Habermas whose "discourse ethics," or "theory of communicative action," depends heavily on the possibility to argue (Habermas 1984, 1987(1981); Habermas 1990(1983)). In his most recent book on these issues, he elaborates on those conditions as follows:

"Whoever makes use of a natural language in order to come to an understanding with an addressee about something in the world is required to take a performative attitude and commit herself to certain presuppositions. In seeking to reach an understanding, natural-language users must assume, among other things, that the participants pursue their illocutionary goals without reservations, that they tie their agreement to the intersubjective recognition of criticizable validity claims, and that they are ready to take on the obligations resulting from consensus and relevant for further interaction" (Habermas 1996(1992), p. 4).

The central point of Habermas' approach is that in modern, pluralistic societies, in which people are at home in different "lifeworlds," social integration can no longer be achieved by means of already shared values and norms. The only way to achieve social integration is by means of communication and argumentation. This way, societies can create and maintain the legal framework they need for a sustainable development, and they can *generate* those norms and values they need for social coexistence. However, all this works *only if* the conditions of argumentation and communication are fulfilled that are mentioned in the quote above. Habermas distinguishes here two conditions, and I would add a third one. First, Habermas highlights that any speech act involves certain *commitments* regarding the "validity" of claims and utterances: "claims to propositional truth, personal sincerity, and normative rightness" (ibid., p. 5). We have to presuppose, in other words, that someone who argues with us is really convinced of the truth of what she is saying, that this person is serious regarding the intentions of her utterance, and the obligations involved in it, and that she herself is convinced of the normative, or moral, rightness of what she is saying.

The second condition Habermas hints at concerns commitments regarding "the obligations resulting from consensus" that are "relevant for further interaction." It does not make any sense to argue with someone who does not commit herself to an agreement reached in this argumentation, and who does not feel responsible for the obligations involved in such an agreement. This, however, presupposes a third condition. Whoever enters the social arena with the goal to reach an agreement must be ready to *change her or his beliefs*. There is absolutely no sense in engaging in a dialogue of "plural perspectives and discourses, different arguments and reasons for them," and in taking part in a "debate in a reflective and critical manner… that can eventually lead to a negotiated solution" (El-Hani and Mortimer), if I cannot expect that *all* participants in those activities are ready to change their mind as a result of this process.

But how could all this be possible if it simply does not matter what students educated by El-Hani and Mortimer believe, and if there is no need to change anything? How can I know whether somebody is serious in what she is saying, or is simply "using" ideas that she "masters" without believing that they are true? From my point of view, there cannot be any argumentation, any serious deliberation and communication, if we avoid to change the beliefs of the people we are talking to. How can I be serious as a teacher if I simply do not care whether my students change their beliefs or not?

Although I am deeply suspicious of El-Hani and Mortimer's thesis that science education should avoid to change students' beliefs, I acknowledge that they are struggling with a serious problem; the problem how science can be taught in environments that do not share basic assumptions of science as they have been developed over the last 3000 years mainly in Europe. As a teacher of philosophy of science, I can understand that there are certain features immanent in scientific knowledge that pose a problem for multicultural education. However, I would handle this problem differently, based on a different understanding of the nature of scientific knowledge.

Scientific knowledge, obviously, is more than a huge set of unrelated statements. It is organized in theories, or represented in models of certain aspects of reality. Although we know from philosophy of science that there are fundamental problems to justify scientific knowledge, that is to defend scientific claims and theories, there is no question that the *attempt* to justify knowledge claims is what distinguishes scientific knowledge from other forms of being sure about something. Justification as an activity—not as a result—is a driving force of scientific development. However, there are two further powers that move things forward: on one hand the goal to achieve coherence, or consistency, among scientific propositions and theories and, on the other, the motive to *generalize* scientific knowledge as far as possible in order to cope with the problem of complexity. Taken together, these three goals of justification, coherence, and generalization lead to a holistic picture of scientific knowledge.

It is easy to see that this immanent holism of scientific knowledge carries with it an 'inborn' tendency that can be called, if seen from the inside of science, *universalistic* or, if seen from the outside, *totalitarian*. Although the amount of what we know in science might be far less than the amount of what we do not know, and even if much of what we claim to know might actually be false, there are no limits of what scientists *want* to know. Sciences study everything that interests scientists and, in this sense, there is no 'outside' of scientific knowledge, no areas of life and the world that are left alone for other forms of certainty. (Note that even religion is an object of scientific studies, not only of theology and religious schools, but also of evolutionary biology, for instance; cf. Atran and Norenzayan 2004). Talking in this way about scientific universalism is not a *normative* or *epistemological* issue—i.e., referring to the question whether science *should* or *can* be universal or not—as discussed by El-Hani and Mortimer, but simply a *descriptive* one. Science itself does not set up any limits regarding what should be known.

Of course, this factual universalism looks very different if seen from an educational, political, sociological, multicultural, or interreligious perspective—as discussed partly by El-Hani and Mortimer. Within those horizons, the justificatory connectedness of scientific knowledge, and its (assumed) coherence and generality, can look like a powerful and total system that excludes other perspectives.

However, it should be an important part of science education itself to emphasize a principal *limitation* of the totalitarian as well as of the universalistic picture of scientific knowledge. In philosophy of science and in epistemology, the term "holism" has been introduced to describe one of the fundamental problems of justifying scientific knowledge. This problem has first been described by Pierre Duhem a hundred years ago. Duhem hinted at the fact that in modern sciences a theory can never be falsified by the not-occurrence of a predicted phenomenon. The reason is simply that in modern sciences any observation depends itself on a "whole group of theories," so that one never knows what exactly has been falsified if things go wrong (Duhem 1906/1997). Tycho Brahe, for example, tried to "falsify" Copernicus' theory that the earth moves around the sun by observing the same fix star at different times of the year. If Copernicus would have been right, so his argument, the angle at which the star is visible must be different each time. However, not even the best available instruments could detect any difference. In Brahe's case, the decisive error was his wrong assumption regarding the distance between this fix star and the earth. As it turned out later, this distance is so large that it was impossible for him—based on his instruments—to detect the difference. What follows from examples like this one is this: the larger the amount of conditions on which a single "observation" depends—theories of the area in question, theories of instruments, available techniques and skills, etc.—the greater the difficulties for identifying the 'real' cause of problems.

About 50 years later, W.V.O. Quine described the same problem under the heading of the "holistic" nature of scientific knowledge:

"The totality of our so-called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even of pure mathematics and logic, is a man-made fabric, which impinges on experience only along the edges. Or, to change the figure, total science is like a field of force whose boundary conditions are experience. A conflict with experience at the periphery occasions readjustments in the interior of the field. Truth values have to be redistributed over some of our statements. Reëvaluation of some statements entails reëvaluation of others, because of their logical interconnections—the logical laws being in turn simply certain further statements of the system, certain further elements of the field. Having reëvaluated one statement we must reëvaluate some others, whether they be statements logically connected with the first or whether they be the statements of logical connections themselves. But the total field is so underdetermined by its boundary conditions, experience, that there is much latitude of choice as to what statements to reëvaluate in the light of any single contrary experience. No particular experiences are linked with any particular statements in the interior of the field, except indirectly through considerations of equilibrium affecting the field as a whole" (Quine 1951/1964, pp. 42–43)

Quine's essential message is that science develops dynamically and—to a certain degree—unpredictable. Since the justification, and falsification, of singular statements is impossible, it is the whole "fabric" of scientific knowledge that is developing. And what can be achieved in this process is not 'truth,' but only a certain 'equilibrium' of the whole thing. It is important to note that these considerations pose problems only for *knowledge claims*, but not for the process of *knowledge generation*. Only for knowledge claims, justification and truth are *preconditions* as noted above. For the process of knowledge generation, they are simply goals, that is ideas that regulate the process without being achieved in any real time, as Charles Peirce put it a century ago (Apel 2001).

From my point of view, a real understanding of science presupposes to know something about the limits of scientific knowledge: the problems of justification, its dynamical character, and its openness for development. Opening up the science classroom for those questions should be the best invitation for students to include their own voice in a dialogue about the prospects and limitations of scientific knowledge, especially if they do not share basic assumptions. But in order to formulate their ideas and considerations, they have to refer to, and to explicate, their own beliefs. An education that enables students to do so must, first of all, take those beliefs seriously. And how can a teacher honor those beliefs more than by treating them as being worthwhile to be criticized and to be improved—based on arguments, not on indoctrination.

To summarize my argument, I would say that El-Hani and Mortimer's central thesis that science education should "avoid" the idea of changing students' beliefs is only convincing in so far as it refers to certain *methods* of teaching: forcing students to accept something to be true without providing sufficient reasons. However, if we want to enable students to participate in real communication, it must be possible to challenge their beliefs—as well as ours.

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Understanding typically yields belief: a neglected point in Hoffmann's reaction to our idea of "culturally sensitive science education"[19]

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Hoffmann argues that the goal of belief change in science education should not be given up, expressing his disagreement with our (and also others'; see, e.g., Cobern 1996; Smith and Siegel 2004) claim that understanding rather than belief is the proper goal of science teaching. Needless to say, we will argue here for our idea that belief change is not a goal to be assumed by science teachers. On the one hand, Hoffmann brings an important contribution to our arguments when he demands a clearer account of what we mean by 'belief', but, on the other hand, he neglects a fundamental idea in our paper when he argues, for instance, that it would be sufficient for us that students can "handle" scientific knowledge without knowing it in the cognitive sense specified in his comment.

Let us address each of these points in turn. It is true that we did not define what we mean by "belief" as clearly as we did for "understanding" in our paper. Consequently, something more should be said about the meaning of "belief", and, even though we cannot expand much on the issue here, we will try to offer some additional arguments. Hoffmann argues that the notion of "belief" remains dangerously ambiguous throughout our paper. We accept that there is some ambiguity in our usage of the term, but we do not think it is as dangerous as Hoffmann argues. He mentions, first, our treatment of belief change in terms of Posner et al's (1982) conceptual change model, focused on the replacement of a person's previous conceptions that play an organizing role in her conceptual ecology by another set of concepts. Then, he notices that we associate "belief" with the basic assumptions about the world held by an individual. In our view, these are two compatible statements about belief, since it is precisely these basic assumptions that play the most central, fundamental role in organizing a student's conceptual ecology, and, in many cases, are in conflict with scientific ideas. It is also consistent to say, then, that the student is likely to *believe in* these assumptions. Indeed, Schwitzgebel (2006), whose "standard philosophical definition of belief" is quoted by Hoffmann, argues that the term "belief" is used in contemporary philosophy of mind to refer to the attitude we have whenever we regard something to be true. Therefore, it is not wrong to link "believing in" with "accepting something as valid or true", which is the basic meaning of "belief" we have in view throughout our paper. Finally, Hoffmann argues that "conceptual change [...] is not

[19] This commentary should be cited as follows: El-Hani, C. N, & Mortimer, E. F. (2007). Understanding typically yields belief: A neglected point in Hoffmann's reaction to our idea of "culturally sensitive science education". *Cultural Studies of Science Education, 2* (3), doi: 10.1007/s11422-007-9064-y.

necessarily connected with either accepting something as true or valid or believe "in" it without reason". It is true that Posner et al's conceptual change model requires that one offers reasons for a replacement of previous ideas by scientific conceptions. But it is also clear that their model is committed to the goal of making a student believe in scientific ideas because she regards it as true or valid—this is expressed in one of their conditions for conceptual change, namely plausibility. The conceptual change model proposed by Posner et al. (1982) entails, thus, the requirement that students break away with their previous ideas (Cobern 1996; Mortimer 1995), and this is precisely the kind of belief change that we argue that it should be avoided in science teaching, *provided that* there are important conflicts between scientific ideas and central, organizing beliefs in students' conceptual ecology. This goal should be avoided because (1) it has a high affective cost to the student, and it is not clear to us that such a consequence of science education can be sufficiently justified; (2) it runs the risk of being disrespectful to other cultural traditions; (3) the attempt to make students break away with their previous concepts is usually not successful, particularly when previous concepts are firmly rooted in socially shared everyday views—and are, thus, very useful to deal with, and to talk about, everyday phenomena—and also when there are important clashes between scientific ideas and students' fundamental beliefs (Cobern 1996). It is important to stress, however, that such clashes do not take place all the time in science teaching, and, when this is not the case, *understanding typically yields belief* (Smith and Siegel 2004). This is a central point in our argument that Hoffmann did not take in due account in his reply, to which we will come back soon. But, first, we should build an argument about the fact that scientistic science teaching is out there in our classrooms.

Hoffmann argues that "nobody in academics […] would subscribe to the idea that scientific knowledge is a question of faith". This is likely to be true among academics, at least for most of them, but we cannot neglect the fact that science is often taught by teachers all around the world as if it was the only source of meaning and truth, among all the variety of forms of human knowledge, as if it was composed of a series of absolutely true theories, about which we can be a hundred per cent certain, since they would be truly pictures of reality as it is. This scientistic approach to science teaching has been called by Smolicz and Nunan (1975) "the myth of school science". Therefore, while we agree with Hoffmann's argument that "a science education that would try to change students' faith, or what they believe in, by indoctrinating them would simply miss the point of science", we do think that many science teachers (and, also, textbooks) repeatedly miss the very point of science in the science classroom. It is the case, then, that it is important to argue that "belief change" in this sense should be avoided, as Hoffmann agrees. But then he asks, what about "belief change" in the sense of conceptual change?

The problem here is that "conceptual change" is a rather polysemous expression. We are certainly against "belief change" in the sense advanced by Posner et al. (1982) in their conceptual change model, for reasons discussed in our paper and in this reply. But the conceptual profile model, which we put forward in our paper as the basis we assume to think about science learning, indeed entails at least two different kinds of conceptual change processes. According to this model, learning a concept involves (1) enriching one's conceptual profile and (2) becoming aware of the multiplicity of meanings the profile harbors and the contexts in which they can be applied. These are forms of conceptual change that can, arguably, embed the kinds of change we look for in science education, and, yet, avoid simply replacing those ideas that are of central importance to a student, and, also, can show heuristic value in a given set of contexts. Symptomatically, Hoffmann did not address the conceptual profile model in his comment. Nevertheless, this model is absolutely central to the understanding of our ideas.

Hoffmann brings another important contribution when he refers to the important distinction between “believing in” and “believing that”. Before discussing this topic in more detail, we should notice that Hoffmann himself brings to the fore this polysemy of the term. It is a polysemy that indeed generates ambiguity and, here, it is important to introduce a cultural difference that may explain why we emphasized more “believing in” basic assumptions about the world than “believing that” a proposition is true. In Portuguese, we rarely use the verb “to believe” to express the latter. Instead, we frequently use something that could be translated as “thinking that” a proposition is true,[20] a use also found in English to express “opinion” (Plato’s idea of *doxa*) as opposed to knowledge (*epistêmê*). In this sense, we think that a proposition is true when we use it almost without conscious awareness. To bring an example that is directly linked to science, most people in Western cultures “think that the Earth goes around the Sun”, but few are able to give a reason to this belief. In our argument, we are much concerned with “believing in” basic assumptions about the world, just because what is at stake when we consider the problems that belief change brings to multicultural classrooms are basic assumptions about the world that are consciously held by the students, which may be challenged by assumptions of the scientific discourse.

This issue is also related to the central epistemological problem of the distinction between “belief” and “knowledge”, which has been recently the topic of an interesting debate involving Cobern (2000, 2004) and Smith and Siegel (2004). This is a topic we consciously left to address elsewhere. We will not be able to discuss it here in the length it deserves, but we have something to say about it now. Hoffmann correctly reminds us that belief is one of the conditions of knowledge. Belief is, in fact, the least controversial condition of knowledge (Smith and Siegel 2004). We concede that this brings an important problem to the claim that science education should aim at understanding, and not belief. Wouldn’t this claim imply that knowledge is not a goal of a culturally sensitive science education, in the sense we advocate? This is a central issue in Hoffmann’s criticism of our position. The problem is quite relevant: if belief is a necessary condition for knowledge, and a science student can understand scientific ideas, but not believe in them, this will mean that in the end the student may not know those ideas. Davson-Galle (2004) raises a similar problem, in his comments on Smith and Siegel (2004). These latter authors themselves ask us to consider the situation of a student who knows that the Earth revolves around the Sun, but does not believe in that idea. Would you think that she indeed knows that the Earth revolves around the sun? They comment that “Virtually all philosophers seeking to analyze knowledge have answered the last question in the negative, concluding that one can know only what one believes—that is, that what one knows is a proper subset of what one believes” (p. 555).

If we argue, then, that a creationist student can be regarded as a successful science learner if she understands the Darwinian theory of evolution, even if she does not believe in it, will we be saying that she does not know that theory, provided that belief is a necessary condition for knowledge? This situation demands that we say more about both the relationship between knowledge and belief, and the proposal that understanding is the proper goal of science education. We will say something more, although we cannot intend to exhaust this theme here.

[20] A more literal translation of the Portuguese expression we have in mind (“Eu acho que”) could be “I guess that”.

It is clear, first, that there is something problematic in simply claiming that one does not know something one understands. We believe that the problem can be somewhat clarified by taking into account that the student could never know, in the example mentioned by Smith and Siegel, that the Earth revolves around the Sun. What she can know is the proposition or statement that this happens. As Hoffmann argues, we believe in propositions. Therefore, we can say that she knows *the proposition* that the Earth revolves around the Sun, but she does not believe *in that proposition*. Indeed, we can say that she knows that proposition, if there is enough evidence that she *understands* what is meant by that proposition and which reasons can be adduced to support it. A person can clearly understand a proposition and the reasons for it, and, yet, conclude that those reasons are not sufficient, in her view, to accept the proposition. It is for this reason that the distinction between understanding the reasons why a proposition is worthy of belief and believing in a proposition is so central to our arguments. A naturalistically minded science teacher can read the Genesis, understand it, and, yet, see no reason to accept it as valid or true. Similarly, a creationist student can understand the Darwinian theory of evolution and does not believe in it, by rejecting the reasons adduced to support that theory. If the student indeed understands that theory, we are in a position to claim that she knows the theory. In these terms, the proposal that understanding is the proper goal of science education arguably maintains its plausibility. It is clear, however, that there is much more to be discussed and developed in our treatment of this theme, so central to epistemology itself. Nevertheless, we should leave this issue to future papers.

Hoffmann also argues that "if we assume that the goal of education is learning, and if a central aspect of learning is the development of knowledge, and if developing knowledge means that we believe, at the end of this process, that something is the case that we did not believe to be the case in its beginning, then giving up the goal of belief change would lead to an education that says "Good bye" to the idea of learning." We think that if learning is seen under the light of the conceptual profile model, this result does not follow. What is wrong with Hoffmann's view of learning is that students do not face the challenge of deciding if they believe that something is the case before understanding what something *is*. Thus, to make sense of something is always a condition for believing in something, the former always takes place before the latter. And sometimes we do not believe that something is the case just because we have an alternative view about the matter, which leads us to believe that another thing is the case. And it is just in these situations that to focus on belief change seems to be helpless. Looking at learning through the conceptual profile model we can see that different zones of the profile lead to different systems of beliefs and different modes of articulating understanding and belief. It is perfectly possible that we do believe that cold objects transfer cold and we do not need to challenge this belief as a way to start learning that in physics there is only one entity, heat, and not two, heat and cold, as we normally believe. At some moment during the teaching process we should address the existence of these two systems of beliefs and how they both function well, each in its appropriate context. Nevertheless, we do not need to take belief change as a goal at any moment to ensure the understanding of these two systems of belief. It will remain part of an individual's freedom to decide in which system she believes more. She should know, however, to which contexts of application each of those systems of belief more properly applies. It is in this sense that the conceptual profile notion helps us give up the goal of belief change without saying ""Good bye" to the idea of learning." Learning according to this model involves putting different discourses into contact, becoming aware of the multiplicity of meanings a specific conceptual profile harbors and the contexts in which they can be applied. We do not assume, as Hoffman says, that "it simply does not matter what students believe, and that there is no need to change anything." We do believe that the process of changing is much more complex that just changing from believing that a proposition is true to believing that an alternative proposition is true. The way we suggested that discursive interactions should be handled in the classroom, allowing for an alternation between dialogic and authoritative discourse, implies that students' ideas should be taken into account and treated respectfully, since there are contexts in which those ideas do apply and are the most useful to handle some situation and to talk about it. It is in this sense that we do not need to challenge a student's belief to make her understand a different and even competing idea. According to the conceptual profile model, teaching avoids a mere confrontation between different beliefs because it considers that each different context entails its own reasons for accepting a specific idea to be true. In this sense, belief is regarded as being tied to particular contexts and particular situations, and to understand a profiled concept also involves knowing the complex interplay between meanings and contexts, and between understanding and belief.

A central aspect of our position was not taken in due account by Hoffmann. He argues, for instance, that we defend the thesis that it should be sufficient that students understand science "without believing that anything that is claimed in science is true, or should be accepted as true". First, the conceptual profile notion entails that students should indeed accept the validity of scientific ideas in the specific contexts in which they have been more successful than alternative ideas. Second, our claim was inadequately generalized by Hoffmann. When we discussed what we called "A dilemma for culturally sensitive science education", we considered the case of a science teacher in a rural area who strives for making her students learn some scientific ideas that might lead them to avoid habits that make them catch some infectious disease, which scientifically oriented people would avoid. We do not argue that the science teacher should give up the goal of making her students accept those scientific ideas as valid or true. Our argument is more subtle: she should aim at understanding, taking into account that we tend to believe in propositions we understand, unless there are some reasons that avoid the typical result of understanding, which is belief. Our argument, then, focuses on specific cases in which belief does not follow from understanding. In these cases, and only in these cases, we argue that there may be important cultural reasons for that result, which are likely to be connected with clashes between fundamental ideas in the students' worldviews and scientific ideas. In these cases, we think that the science teachers should not try to shape the content of students' beliefs directly. This would be quite close to an effort to change student's faith by indoctrinating them, precisely the kind of science education Hoffmann himself thinks that it would miss the very point of science. After all, while teaching for understanding, a good science teacher will offer the reasons for the scientific statements at stake. If the students are successful science learners, they are likely to understand both the statements and the reasons why they are worthy of belief. Nevertheless, they are still in a position in which they may reject those reasons, and a putative factor leading to that result is a clash with their worldviews. Understanding typically leads to belief, but, when it does not, if the teacher did her job well in teaching the scientific statements and the reasons underlying them, and the students also did their jobs well in learning those statements and reasons, there may be good reasons (from a culturally based perspective) underlying that result. And we, as science teachers, cannot simply neglect those reasons.

Therefore, we do not agree that the kind of learning we have in view in our paper is "fake-learning", as Hoffmann argues. Only by neglecting the fact that belief is the typical result of understanding and the nature of learning in the conceptual profile model, one can come to this conclusion. It is not sufficient, in our view, that students handle scientific knowledge without knowing it in the sense that they are in a certain cognitive state of accepting something as true. We discussed above, although briefly, how we think of the connections between belief and knowledge. Furthermore, the typical result of science teaching focused on understanding will be a certain cognitive state in the students that make them likely to accept scientific ideas as true. But there are situations in which they will not accept them as true. It may be the case that important cultural reasons intervene with the learning process, impeding that the typical result of understanding takes place. These reasons should be taken seriously. If we do not accept the result that a deeply religious student understands the Darwinian theory of evolution, and the reasons for it, and, yet, reject those reasons, and, then, we strive for making her believe at all costs in the propositions composing that theory, this would amount, in our view, precisely to the kind of science education Hoffmann himself intends to avoid. But notice that science teaching should indeed lead the student to appraise the Darwinian theory and the reasons for it, and, if she still rejects it after science learning, a good result is that she can now be much more rational and critical about that rejection—she would not reject the theory, then, simply because somebody told her to do so, but because she understood the theory and appraised the reasons for it. Even though science teaching did not promote belief—something we think it is not its proper goal—, it is the case that it promoted rationality—and this is, in our view, a fundamental goal of education as a whole.

It seems clear to us, then, that the criticism that we would be committed to "fake-learning" can only be made by neglecting the fact that we are focusing on specific circumstances in which there are serious reasons that avoid that belief result from understanding. If there are—indeed—costs in mastering and using ideas without accepting them as true, there are also costs in forcing a student to believe that some proposition is true even though she understood the proposition and the reasons adduced to support it, and, yet, rejected those reasons and, consequently, that proposition. These costs range from affective costs to the student, failure of science teaching (by being often unable to reach a critical mass of conceptual change, in the face of the strength of the student's commitment to her worldview), and even risks of cultural erosion, in the most extreme cases.

Hoffmann takes Habermas' theory of communicative action to discuss the conditions for the communication and argumentation required in order to achieve social integration in our plural societies. Certainly, Habermas brings important contributions to the understanding of what we call the social arena of argumentative processes. Hoffmann considers the following condition for communication and argumentation: "*all* participants in those activities are ready to change their mind as a result of this process" (emphasis in the original). Fair enough. But it is a fact of life that no human being is entirely open-minded. Depending on our cultural experiences and background, we can be more or less open-minded, but nobody is ready to negotiate the meaning of all ideas one can be committed to. We face dialogue in our social circumstances always with a series of restrictions, commitments, etc. In particular, when we are talking about people's most fundamental ideas, which play a central role in organizing their understanding of themselves and the world around them, it is simply a utopia to claim that we should be all ready to change our minds in the process of communicative interaction. We should, indeed, educate our students to be as open-minded as possible, and science teaching can play quite a central role in this process, due to the nature of scientific work and scientific knowledge. Nevertheless, we should be always ready to situations in which understanding does not yield belief, and it is in these specific circumstances that we are particularly interested in our paper. After all, they arguably pose the most serious challenges for multicultural science education.

Finally, we should say that we agree with Hoffmann in that a teacher can honor the beliefs of her students by treating them as being worthwhile to be criticized and even improved by arguments. Fay's distinction between being respectful and simply accepting every idea a student may have is instrumental in this respect:

> I don't respect a student by accepting everything he or she says […]. Respect demands that we hold others to the intellectual and moral standards we apply to ourselves and our friends. Excusing others from demands of intellectual rigor and honesty or moral sensitivity and wisdom on the grounds that everyone is entitled to his or her opinion no matter how ill-formed or ungrounded, […] is to treat them with contempt. We honor others by challenging them when we think they are wrong, and by thoughtfully taking their criticisms of us […]. So if respect is to be the chief value of multiculturalism then it cannot simply mean acceptance. (Fay 1996, p. 239)

But notice that we are particularly worried about situations in which a student, who understood the teacher's arguments and appraised the reasons underlying them, still clings to her beliefs, by considering that she cannot accept those reasons. In this case, if we move to belief change as a goal, there is no other result than indoctrination. And this should be avoided, both Hoffmann and we agree. It is our contention, then, that, since understanding typically yields belief, if we focus on understanding as the goal of science education, we will usually get belief as a result, in situations in which this is appropriate, and we will also be able to avoid scientistic, indoctrinating science teaching.

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