

Complementary Epistemologies of Science Teaching: Towards an Integral Perspective

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Abstract

For over two decades, science education has been a site of struggle between adherents of the apparently antithetical epistemologies of objectivism and constructivism; recently, proponents of personal and social constructivism have locked horns. However, at the beginning of the 21st Century, we feel that it is timely for science education to enter an age of pluralism, of tolerance for multiple and competing ways of knowing, in which no one way is ultimately privileged; to exercise humility about the authority of our cherished ways of knowing the world around us. In the interest of creating greater equity of access amongst students to a much richer encounter with science, a new mode of pedagogical reasoning is needed. From the perspective of constructive postmodernism, we propose dialectical thinking as a way of generating unity-in-diversity, and metaphor as a key referent for overcoming the obstacle of literalism which tends to reinforce fundamentalist notions of difference. We illustrate the viability of an integral perspective on science teaching with a brief account of an inquiry into the scientific literacy of a class of junior high school students, from which emerged a 3-metaphor framework. Mindful of the limitations of this framework, we argue for science education researchers to join us in conceptualizing more powerful and compelling integral metaphors for promoting worldwide epistemological pluralism and cultural diversity.

Introduction

Over sixty years ago, Dewey reflected that the history of educational theory is marked by opposition (Garrison, 1995). It seems that this is true also of recent educational history where 'paradigm wars' are well established between proponents of the disparate epistemologies of objectivism and constructivism (and between those who favor one form of constructivism over another). Clearly, each of these epistemologies serves contrasting purposes in science education, with constructivism currently in the ascendancy in national curriculum frameworks.

However, relentless competition amongst theories may promote a tendency for science education to move through cycles of fashionable ideas, only to return ultimately to the starting point, resulting in teachers becoming cynical about the latest curriculum development 'fads' (Fullan, 1993). It may also contribute to a sense, especially amongst teachers, that educational researchers do not or cannot contribute significantly to 'real' educational issues within schools.

These are significant reasons for science educators to consider establishing an integral perspective which endeavours to unite otherwise disparate energies (Settelmaeir & Taylor, 2001). In this chapter, we consider first divisive antinomies amongst proponents of single epistemologies such as objectivism, personal constructivism and social constructivism, and contrast this with a call for epistemological pluralism. Next, in the interest of generating more inclusive science teaching aimed at enhancing scientific literacy, we present an argument for uniting these seemingly divergent epistemologies. This involves using dialectics as a mode of reasoning and using metaphor as a key referent for pedagogical and curricular reform.

Privilege or Pluralism?

For over 25 years, the ‘thesis’ of constructivism has challenged science teachers’ traditional understanding of their classroom role as transmitters of objective knowledge. Proponents argue that the ‘anti-thesis’ of objectivism evokes an outmoded image of knowledge as an entity progressively accumulated and stored in memories and books. They argue that an objectivist view of learning uses an exclusive metaphor of knowledge transfer which assumes a single (teacher) explanation can fit all receptive (student) minds. In sharp contrast, constructivist-inspired curricula reform calls for pedagogical practices that enable all students to ‘make good sense’ of their learning experiences.

Science education research has responded by developing constructivist-oriented teaching strategies for taking account of students’ prior knowledge, interests and aspirations. Continuing developments in constructivist theory have highlighted the social context of learning, and the focus of constructivist-inspired teaching is shifting onto the role of language and communication skills in building dialogical learning communities. From a critical social perspective, constructivism highlights the disenfranchisement of students under objectivism, and looks for evidence of the benefits of more socially inclusive modes of teaching and learning.

Undoubtedly the notion of a superior educational theory has an appealingly parsimonious quality. However, as Dewey reflected, the rancour that develops around the aggressive-defensive posturings of proponents of either side can be counter-productive. The science education literature is replete with the competitive voices of proponents of single epistemologies of teaching and learning. For example, Kragh (1998) has argued from an objectivist perspective that constructivism is ‘philosophically unsound’, has ‘weak empirical support’, is ‘subversive...to honesty and critical thought in general’, and constitutes ‘a frontal attack on the entire edifice of science’ (p.242). On the other hand, Guba and Lincoln (1989) have argued from an avowedly constructivist perspective that the objectivist paradigm ‘needs to be replaced’ (p.43).

This contestation is not confined to the apparently antinomic theories of objectivism and constructivism. Favouring social constructionism, Gergen (1995) has argued that the way earlier forms of (cognitivist) constructivism depicted the mechanism of communication was a ‘pitiful accomplishment’ (p.28). O’Loughlin (1992) has advanced this rhetoric in claiming ‘that the universalist, rational, disembedded thought valued by Piagetian [personal] constructivists is...ideologically bound and must be rejected in favour of a more suitable ideology’ (p.809). Defending personal constructivism, Fosnot (1992) has countered that the social constructivist model is ‘nihilistic, culturally relative, and dangerous’ (p.1189).

In science education there is, however, an emerging agenda for epistemological pluralism, that is, for multiple epistemologies (i.e., theories of knowledge or ways of knowing) to be regarded as affording mutual perspective-building ways of informing us about student (and teacher) learning. But if we are to pursue this trajectory towards a more pluralistic and tolerant community, we need good reasons for doing so. Calabrese-Barton and Osborne (1998) point the way with questions about how to achieve more inclusive science teaching:

- How can historically marginalised students become involved in science?
- How can we shape practice and curriculum to address the needs of diverse learners?

These and many other contemporary calls for ‘science for all’ are directing teachers of science to account for differences amongst students in cultural background, language and gender. Indeed, an ethic of inclusivity demands a fresh approach to providing science for all students, and it is our belief that a complementary perspective on the utility of contrasting epistemologies may help to achieve this elusive social goal.

Complementarity

Postmodern curriculum theorists (Pinar & Reynolds, 1992; Slattery, 1995) warn that the philosophy of modernity has restricted our (Western) ability to reason by privileging Cartesian binary and dualistic thinking. When confronted by contradictions inherent in oppositional aspects of reality – male and female, body and soul, thinking and feeling, person and world, light and dark, good and evil, immanence and transcendence, particularization and generalization, theory and practice – we automatically resort to well established modes of reasoning. The most common is domination and/or destruction, in which we try to control or eliminate the oppositional pole in order to eliminate the contradiction. This is evident in the contestation amongst proponents of opposing epistemologies in science education.

A less common approach is to engage in dialectical reasoning and attempt to transform both poles of a contradictory set of metaphors into a higher level of understanding. The classical form of (Hegelian) dialectic is to pursue perfect society or ultimate truth by debating thesis and antithesis until a new synthesis emerges as a point of departure for a further dialectic. However, little purchase is provided for honouring the integrity of the thesis or antithesis or of the unique connectedness of these parts to the overall whole.

On the other hand, constructive postmodernism views the world as complementary and organic, and recognizes that the strength of the whole is derived from a respect for the contribution of each part. In the symbolic circle of the yin and the yang, masculine and feminine principles of light and dark blend together in a permanent dance of continuous improvisation. The notion of ‘dialectical complementarity’ focuses on the relationship between the seemingly opposing parts; and conceives the relationship to be more akin to a sacred dance than a power struggle. It allows us to seek unity-in-diversity without rejecting one of the parts or merging the parts into a new synthesis.

From a constructive postmodern perspective, dialectically complementary epistemologies - objectivism, personal constructivism, social constructivism (amongst others) – can provide a set of unique ways to enable students in science classes to make sense of the natural world. As we shall argue, each epistemology provides a different focus for learning, a different means of engaging in the process of learning, and a different set of possible learning outcomes. An integral perspective affords opportunity for students to learn about the nature of complementarity itself, that is, the philosophical (and socio-political) ‘dance’ between contrasting epistemologies, within science and without, down the ages and across cultures. Through reflection on the (normally invisible) epistemological framing of their own learning in/about science, students may experience something of the richness, complexity and contingency of the scientific worldview that endeavours to shape (enrich? distort?) their cultural identities.

However, our argument for an integral perspective cannot rest solely on the principle of complementarity. There is another obstacle that we need to deal with: the tendency towards literalism.

Metaphor

If, during a conversation, one speaker exclaims, “I see”, when she actually means, “I comprehend”, and the other turns to gaze in the same direction, then effective communication is restored only when the second person realises the metaphorical nature of the first person’s comment and the inappropriate literalism of their own initial interpretation. Equally, if one chooses to use in a metaphorical sense the terms ‘objectivism’, ‘personal constructivism’ and ‘social constructivism’, then communication will be difficult with those who use them in a literal sense. Indeed, we believe that a complementary view of these epistemologies is impossible if a literal view persists, especially one that entails a ‘competing theories’ notion of their relationship.

Through the lens of the literal we presume to see things as they 'really are', yet many (perhaps most?) of our concepts have metaphorical structurings because of the embodied structuring of mind (Lakoff & Johnson, 1999). Many everyday commonsense expressions – 'that's a clear argument', 'what's your outlook?', 'I've got the picture' – constitute a metaphorical mapping of our sensorimotor-based knowledge about human vision onto the domain of understanding or knowing. Whenever we conceptualise aspects of mind in terms of expressions such as 'grasping ideas', 'reaching conclusions', 'being unclear', or 'swallowing a claim', we are using metaphor to make sense of what we do with our minds. Indeed, we utilise a variety of metaphors that structure the way we conceive of mind: 'mind as body system', 'mind as builder', 'mind as computer', 'mind as container', 'mind as machine' and 'mind as person'. Some of these metaphors give rise to seemingly incompatible perspectives, yet each has a certain viability and currency in its usage (Ernest, 1995; Lakoff & Nunez, 2000).

Metaphor is central also to science. 'Science' - to know, may derive etymologically from a root word meaning 'to cut' - a 'knowing through cutting' (Klein, 1971). To say that scientists have been 'cutting into the fabric of the universe' is using metaphoric language to suggest that they have been doing experimentation or theorisation about the nature of the universe. However, to say that they are conducting 'scientific research into the nature of the universe' has a literal resonance which masks the metaphoric origins of the term 'science', thereby rendering it as a 'dormant' metaphor. Thus 'science' comes to be viewed no longer as a metaphor but as a literal term conveying a precise meaning.

Not only the origins of the concept, but the ongoing practice of science relies strongly on metaphor. 'Plum-pudding', 'solar system', 'wave' and 'cloud' have all been applied metaphorically, successfully or unsuccessfully, to the phenomenon labeled 'atom'. Diametrically opposed ways of conceiving of phenomena can and do co-exist because of fundamentally different metaphors. The wave-particle duality model of light is a classic example.

Metaphor is central also to the communication of scientific ideas. The register of science makes use of nominalising active processes. Verbs that describe observable processes, such as 'moving', 'refracting', 'gravitating', are transformed into nouns, thereby creating (fictional?) entities, such as 'motion', 'refraction' and 'gravity'. This linguistic process has been termed 'grammatical' metaphor (Halliday & Martin, 1993). The metaphorical basis of language and thought means that metaphor is not just an important conceptual tool, but is doubly-buried in the register of scientific English in its expressions and grammar. This implicit use of metaphor tends to make the scientific register seem like a foreign language, all the more bewildering because it seems in many respects to be familiar.

A hallmark of metaphor is that it dispenses with the proprieties of literalism and takes the risk of merging elements and discourses that are supposedly incompatible. The metaphorical impulse might thus be described as dialogic (Seitz, 1999). It is the discursive, risk-taking, merging-of-the-incompatible nature of metaphor that, we believe, provides it with the credentials to help facilitate multi-perspectival dialogue amongst proponents of the epistemologies of constructivism and objectivism. If science educators presently holding a commitment to a single epistemological perspective are willing to accept the metaphorical basis of not only their own epistemology but also of alternative epistemologies, then a complementary notion may gather momentum. But this dialogue can be fuelled only if we can demonstrate that objectivism and constructivism are metaphoric in nature, especially in the context of science teaching and learning.

Metaphors of Constructivism

When Kelly used the term 'constructing', he referred to the action of building things that were apprehendable by the senses, such as bricks and wood, and carried it over to building thoughts. As such, it is clearly metaphorical (Spivey 1997). An appeal of the metaphors of constructivism – making sense, constructing understanding, building ideas – is their dynamism, suggesting that

mind is actively involved in manufacturing ideas. The term 'constructivism' has attracted numerous modifiers, and two of these are of interest here: personal and social constructivism.

Personal constructivism can be rooted either in the work of Kelly or Piaget, and focuses on the mindful activity of individuals engaged in making sense of the world. In science education, personal constructivism appears in two forms. The most popular form construes the learner as constructing mind-dependent understandings of natural phenomena. This 'weaker' form of constructivism fits comfortably (for many) with a view of established scientific knowledge (e.g., scientific laws) constituting a close approximation to the 'reality' of the natural world. From this realist perspective, absolute truth is approached asymptotically by science. In science education, the weaker form of personal constructivism has fuelled a fruitful research program into conceptual frameworks and misconceptions, and has been instrumental in the development of pedagogical models of cognitive conflict and conceptual change that serve to replace non-scientific views of the natural world with views consistent with the canonical knowledge of science. Associated teaching metaphors include 'assessment as a window into students' heads', and teachers as gardeners, tour guides and learning facilitators (Tobin, 1990; Roth & Roychoudury, 1994).

A stronger form of personal constructivism - radical constructivism - arises from the work of Piaget (and from the ancient Greek tradition of 'scepticism') (Steffe & Thompson, 2000). From this perspective, we construct our understandings of natural phenomena by reflecting not directly on the world itself but on our experience of the world, and so our resultant knowledge can be judged only in terms of its viability, or degree of fit with our experiences. Because our experiences include negotiating with others, our sense-making is mediated by the way others make sense of their experience of the same phenomenon. Thus the problem of extreme idiosyncrasy (solipsism) is avoided as long as we negotiate meaningfully and sincerely. From this perspective, scientific knowledge can be judged only in utilitarian terms: does it work well for whatever purpose we have in mind? This is a pluralist (some say 'relativist') perspective that helps to provide an opportunity for discussing the viability of varying views on what constitutes a good or worthwhile purpose for science.

The term 'social' modifies the metaphor of constructivism to indicate the interpersonal dimension of knowledge construction, in which individual sense-making is understood to be mediated by social interactions (Tobin, 1993). In science education, social constructivism has enriched our pedagogical perspectives on classroom learning by promoting the importance of engaging students in dialogical activity, including collaborative learning and consensus building: 'learning as co-participation' is a typical metaphor. Coupled with the weaker form of personal constructivism, social constructivism is concerned with shaping 'microsocial' classroom activity, that is, with ensuring students are active participants in a dialogical community concerned with developing the canonical knowledge of science. This can be viewed as a process of (largely uncritical) enculturation into the worldview of science, an important process that prioritises the production of future scientists.

The stronger program of social constructivism arises from numerous sources, including, the new sociology (Berger & Luckman, 1966) and recent elaborations of radical constructivism, including cultural, critical and postmodern perspectives on the role of language, culture and politics in serving the interests of dominant societal groups (Cobern, 1998; Taylor, 1998; Taylor & Cobern, 1998). Critical pedagogies are beginning to emerge in science education, fuelled by ethical principles of cultural inclusiveness, fairness and equity. Science education researchers in indigenous communities embedded within Western nations are currently articulating culture-sensitive science curricula and teaching strategies (Aikenhead 2000). Japanese science educators are arguing from cultural and linguistic perspectives that Western science should be taught as a foreign language in order to protect the integrity of traditional Japanese culture (Ogawa, 2002; Kawasaki, 2002).

Thus, at the heart of increasingly elaborated constructivist theory lies the metaphor of constructing. But what of objectivism?

Metaphors of Objectivism

The tricky thing about objectivism is that because it is a 'dormant metaphor' that has lost its metaphorical appearance it is usually taken literally. When we consider objectivism from a metaphoric perspective it loses much of its threatening dogmatism. Objectivism has as its root a noun, 'the object' (Sutton, 1993) which is pre-eminent and must be studied rigorously as though (metaphorically speaking) scientists can slowly, progressively and communally reveal an underlying reality. A basic tenet of objectivism is that communities of scientists can be confident that, by utilising certain methodological standards, they seem to be coming to increasingly more accurate knowledge about phenomena in the world; seeing them more clearly, perhaps.

Indeed 'knowing as seeing' is a common metaphor associated with both objectivism and constructivism. With objectivism the seeing metaphors are suggestive of 'uncovering' facts and making knowledge 'discoveries'. 'Understanding' is a metaphor associated with taking a (sensory) position from beneath, with the implication of looking up (at the underside) of something. 'To come at it from another angle', a metaphorical expression of how to understand something, gives greater weight to the object in view, as if a partial circumnavigation is required in order to reach a different vantage point from which to more clearly see the object. 'Point of view' is a metaphor for opinion - the viewing point determines the view - yet the phrase has been widely construed to mean 'the view itself'. So, despite the pre-eminence of the object in objectivism, understanding the object is clearly perspectival.

In terms of the learning process, objectivism gives rise to metaphors of 'knowledge as an entity' and 'knowledge as transferable' - which fit a conduit or pipeline metaphor suggestive of communication as an exchange of ideas, as though (metaphorically speaking) ideas can be placed into students' well-prepared minds (Costa 1993; Jonassen, 1991). These knowledge metaphors relate closely to Lakoff and Johnson's (1999) 'thinking as object manipulation' metaphor, in which ideas are regarded as objects that can be played with, tossed around or turned over in one's mind; thus, to understand an idea is (metaphorically speaking) to grasp it, to have it firmly in one's mind.

Roth and Roychoudhury (1994) have claimed that objectivism is the 'default epistemology' for children in Western schools because it is the only epistemology available. What we are suggesting is that if the concept of objectivism is understood in metaphoric (rather than literal) terms, it may have a legitimate role as a (but certainly not 'the' only) referent for shaping the teaching of science. Indeed, it may be legitimate at times to teach as though knowledge is transferable, as though reality is being uncovered, as though ideas are objects (metaphorically speaking, of course). The pedagogical challenge is to justify the conditions under which objectivist metaphors should be used as pedagogical referents; the key question being: 'for what well-justified pedagogical purposes'?

A further interesting question concerns the interaction between the metaphors of objectivism and constructivism: under what circumstances can they co-exist? We have already indicated that the weaker constructivist program is compatible with objectivist metaphors and that they are likely to be alive (albeit perhaps unwittingly) in the teaching of reform-minded science educators employing conceptual change strategies. On the other hand, it seems unlikely that the strong program of constructivism is compatible with objectivist metaphors, but is this because this program is taken literally rather than metaphorically? Or is there something intrinsically incompatible about some of the metaphors of constructivism and objectivism? Do they, perhaps, have distinctively different domains of applicability? Or perhaps our dualist thinking is getting the better of us, and a dialectical rationality is needed to hold apparent antinomies in tension, perhaps seeking a higher order synthesis. Such a perspective is compatible with Wilber's (1999) integral philosophy which holds that any phenomenon can be understood from four distinct perspectives (arranged in his 4-Quadrant Model) - subjective, intersubjective, objective, interobjective - each of which has its own particular truth claim; none

is privileged, each provides a unique and legitimate understanding of the world (Settelmaier & Taylor, 2001).

So how can complementary metaphors be developed for science education?

Scientific Literacy as Complementary Metaphors

A recent interpretive case study of Year 9 science teaching and learning was conducted with the aim of identifying factors that influence students' engagement in learning science. The research was motivated by a concern to overcome obstacles to equity of access amongst students to 'scientific literacy', a term that has many meanings in the literature extending back over 30 years. During the one-year period of fieldwork, a recursive process of analytic induction was undertaken in which data analysis informed and was informed by ongoing reviews of the extensive literature on scientific literacy (Erickson, 1998). Three metaphors emerged from this process and provided somewhat of an integral framework for interpreting the learning experiences of students who were 'tracked' throughout their school day: 'student-as-recruit', 'student-as-judge' and 'students-as-scientists'. Each metaphor gives rise to a distinct epistemological view of pedagogical goals and students' classroom roles (Willison, 2001).

The metaphor of student-as-recruit emphasizes students accessing and appropriating canonical classroom-science (i.e., content and skills), and is most closely aligned with the epistemology of objectivism. Students work in labs on prescribed 'cook-book' tasks, designed primarily to illustrate scientific theory and to develop important practical skills associated with doing science. This form of teaching is well aligned with the non-inclusive goal of preparing an academic elite for entry into the professional field of science (and science teacher education).

Student-as-judge is a metaphor that emphasises individual students' evaluation of the knowledge claims of classroom-science. Ultimately, students are persuaded one way or the other about the validity of a scientific claim, however to be recognised as participating in this manner the student needs to manifest some type of judgement about a classroom-science notion being presented by the teacher. The focus of this metaphor is on the sense-making activity within the mind of the individual student, and is aligned with the epistemology of personal constructivism.

Students-as-scientists is written in the plural because the metaphor emphasises social (constructive) processes in the formation of scientific literacy. This metaphor is demonstrated when students develop their own knowledge claims about phenomena and attempt to persuade others about the validity of their claims. Developing their own knowledge claims involves asking their own questions, devising their own experiments, producing their own results and conclusions, and engaging in reflective discourse on the viability of their knowledge and the way it was generated.

The viability of the three-metaphor framework was established by using it to organize a representative selection of the research literature on scientific literacy, dating back to 1972. Of 44 articles analysed all but two contained definitions of scientific literacy that fitted the three-metaphor framework (Willison, 2001).

Complementarity Lacking in Practice

A year of participant-observation in two Year 9 junior high school science classrooms in a government-controlled inner-metropolitan school in Perth, Western Australia, revealed that students were engaged almost always in enacting the role of recruit (Willison, 2001). In science labs it was unusual to observe anything other than relatively closed investigation tasks in which problem, method and solution were largely predetermined by the text book. Students learned (implicitly) to ignore their 'errant' methods and 'ill-fitting' observations in order to ensure that they were assessed by the teacher as having confirmed classroom-science canonical knowledge and to have conformed closely to its standard discourse practices.

On occasion, a student was seen to be functioning in the role of student-as-judge, especially when judging the classroom-science to be at odds with his/her own life-world experiences. For example, Shelly had observed her father welding and had noticed how the welding material had 'shrunk' into the gap after being heated. From this experience she inferred that metals shrank when heated (as magnesium ribbon appears to do when burnt), and she applied this tenacious understanding to explain the famous heated 'ball and ring' experiment. She argued that when heated the ring 'shrank outwards' thereby allowing the ball to pass through! However, Shelley's science teacher failed to probe her ideas when she offered them in class discussion. After much frustration, Shelly eventually 'accepted' the classroom-science canon that metals expand when heated, although further research revealed that she did not believe her teacher or fellow students, and concluded that "Science is stupid, 'cause you don't know if you're right!"

A more epistemologically astute teacher may have encouraged Shelly to voice her alternative ideas, along with those of other students, and managed a discussion about their viability, perhaps discovering appropriate life-world contexts in which students' alternative ideas make good sense. If students are encouraged to judge the classroom-science by identifying perceived deficiencies then fewer students may become alienated from science. When alternative student understandings "are not treated as candidate challenges to accepted scientific knowledge but as erroneous and explained by external factors, the teacher suggests that science offers an unfailing accurate and thorough description of the world as opposed to providing the means of participating in the scientific construction of reality" (Costa, 1993). Such a non-inclusive approach might not seem helpful to a student who is struggling to make scientific sense of phenomena.

On one occasion during the year, students were involved in an open investigation into parachutes, which presented an opportunity to enact the role of students-as-scientists. Shelly seized the opportunity, designing, conducting and reporting persuasively her own experiment. Because parachutes were of interest to her out of school, she designed a unique investigation into the relationship between parachute shape and time of fall, keeping constant the surface area, weight and drop height. Most students chose to investigate the simpler relationship between drop height and time of fall (suggested by the teacher). Although she was constrained to work individually, Shelly displayed some important hallmarks of the students-as-scientists role inasmuch as she developed a genuine and relevant research question, enjoyed ongoing freedom of experimental design, generated empirical data and accounted for invalid readings, and reported persuasively about her knowledge claims in terms of classroom-science criteria (i.e., controlled variables, use of mathematical equations, repeat trials, and a null hypothesis).

It is interesting to note that Shelly's success in the students as scientists role was dependent, in part, on her student as recruit skills. Bordieu and Wacquant (1992) have argued that "historians and philosophers of science, and especially scientists themselves, have often observed that a good part of the craft of the scientist is acquired via modes of transmission that are thoroughly practical" (p.223). Thus, utilising the students-as-scientists metaphor may help facilitate student learning of classroom-science knowledge, thereby enhancing the role of student-as-recruit. Greater scope in the science class for enacting the roles of student-as-judge and students-as-scientists might provide more meaningful learning activities for a greater range of students as well as enabling students to develop richer (more complex) understandings of the nature of science.

Towards An Integral Perspective

However, we acknowledge the limitation of the three-metaphor framework which tends to promote a narrow view of the aim of science education as enculturation into a canonical science worldview. This limitation arose in this study from the narrow range of epistemological perspectives embedded historically in the literature of scientific literacy (mostly objectivism and the weak program of constructivism) and from empirical inquiry into the restrictive practices of

two science teachers. When we think more broadly about an integral approach to science education, one that promotes cultural pluralism, we are thinking about visionary pedagogies that include epistemologies of objectivism and constructivism, especially the strong program of constructivism.

A good example of a potentially integral metaphor is Aikenhead's (2000) notion of 'learning as concept proliferation'. This metaphor was developed from a concern to create a culturally inclusive curriculum of school science for First Nations communities in Canada. Whereas the popular pedagogical model of conceptual change tends to support a view of learning science as 'one-way border crossing', in which indigenous children's non-Western cultural knowledge is replaced by the cultural knowledge of Western (school) science, concept proliferation allows indigenous students' life-world concepts to exist alongside scientific concepts, thereby helping to promote their development as 'two-way border crossers'. In Mozambique, a science teacher educator recently conducted a critical autoethnographic study of her own university teacher education practice and found the concept proliferation metaphor helpful in enabling her to resolve the paradox of teaching Western science while honouring her cultural traditions.

Maybe the way to hold this paradox is by making clear those different worlds and assuming different roles in accordance with the different situations. Playing the role. As a teacher, my challenge should thus be to allow all these personalities to live in me without conflict - to understand science but not necessarily believe in it and to understand my culture, in which I have strong beliefs. Rather than seeing them as conflicting, allow them both to be in my inner self and so become able to play the outer role. Not requiring my students to engage in 'concept-replacement' - "replacing common sense concepts they have constructed or learned from others" (Aikenhead 2000), but rather promoting 'concept-proliferation' - not allowing students to throw away their common sense views in favour of the (Western) science view.

(Afonso & Taylor, 2003, p. 12)

We find it exciting to imagine the future possibilities for epistemological pluralism in science classes where potentially integral metaphors, such as 'learning science as a foreign language' (Ogawa, 2002; Kawasaki, 2002) and 'learning science as concept proliferation' (and others yet to be conceived), are employed by astute teachers to enrich the learning environment and provide students with the confidence and skills to deal critically and creatively with the dialectical tension between their growing scientific objectivity and evolving cultural identities.

In Closing

In responding to Dewey's call to approach conflict in education from 'a level deeper and more encompassing', we feel that it may be better to background the notion of 'theory' because it tends to evoke a competitive and mutually exclusive standpoint. For many years under the auspices of objectivism or constructivism, science education researchers have fortified their respective research programs and refuted competing theories. The competition is understandable when 'theory' is the underlying conception of the nature of these contrasting epistemologies.

We have argued in this chapter that metaphor, rather than theory, has the capacity to facilitate an integral perspective by allowing divergent epistemologies to be perceived as complementary, as united in diversity. In this vein, Lakoff and Nunez (2000) argue that "each mode of metaphorical understanding has different uses. And each is precise in its own terms....But you do not have to choose. As long as you keep your metaphors straight, you can use whichever is most useful for a given purpose" (p.374). We propose the somewhat controversial view that objectivism, personal constructivism and social constructivism are metaphorical in origin and substance, that each is significant, and that together they are not mutually exclusive, but rather can provide different viable and valuable understandings about science teaching and learning (and the nature of science). In making explicit the metaphorical

bases of these divergent epistemologies, and arguing for a mode of reasoning involving dialectical complementarity, we hope to contribute to a more productive dialogue amongst the proponents of single epistemologies in the science education community.

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