Chapter 4
Cultural Studies of Science Education: An Appraisal

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4.1 Introduction

The Cultural Studies of Science Education (CSSE) became prominent in 2006 with the launching of the Springer journal of the same name. The field has in the past decade developed a congeries of inter-related theses about the nature of modern science as a human activity and correspondingly of science education. Yet some of the theses most deeply entrenched in CSSE scholarship actively obstruct the role of scientific inquiry in providing genuine knowledge[1] of the dynamic interactions that constitute the world (or the universe, reality, existence, or simply, *what is*).[2] Science education, if it is to serve both its intellectual and social purposes, must be undergirded by a sound conception of the general nature of the process of modern scientific inquiry, and an understanding of the nature and value of scientific knowledge.

Developing a thorough knowledge of the determining factors of physical and social problems through the process of scientific inquiry is a necessary condition for developing, testing and refining active solutions to those problems. Developing a widely shared cultural consensus on the value of scientific knowledge and hence of scientific method is also necessary, if in a democratic society the political will is to be gathered to take social action based on that knowledge. One of the cultural purposes of primary and secondary science education is to lay the groundwork necessary for building that social consensus.

But, there is currently a disturbing disinclination, in some quarters, to see modern scientific inquiry and knowledge as relevant to solving social/cultural/physical problems. Cordero, in 2001, states that modern science offers an account the world

[1] Epistemological questions regarding the characterization of knowledge are taken up later in the chapter.

[2] See McCarthy 2014 and McCarthy 2017.

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that in its detail and coherence is so far superior to other accounts that "A scientific culture is correspondingly on the rise, centered on this [scientific] picture and its attendant style of thinking" (p. 2001). Cordero also notes that "Opposition to according science special intellectual prominence is not in short supply" (p. 18). It seems that currently the opposition to the knowledge generated by modern science is in many quarters culturally ascendant. I will argue that the prevalence in science education of erroneous post-modern interpretations of the nature of science, the nature of knowledge, and the nature of truth contribute to the social problem of cultural disdain for, or neglect of, modern science, its practices and its findings.

Wolpert (1992) argues that the scientific attitude, the inclination to engage in extended experimental inquiry to reach well-warranted beliefs about the world, is an attitude that generally requires cultural inculcation. Given the stringent norms of science proper, Wolpert argues, the scientific attitude is unlikely to arise naturally, in the absence of extensive education in and about science. That education is difficult to achieve, because understanding scientific inquiry requires understanding complex sets of abstract theoretical formulations about the dynamics of the world. The scientific knowledge about the world that is achieved tends to be highly counterintuitive. While it is not to be expected that all students will become scientists, in a modern society all students should develop a basic comprehension of the scientific inquiry and knowledge upon which the society depends. In the absence of a general commitment to high quality science education, the general scientific competence in a society is likely to be insufficient to promote, and to demand, the use of scientific knowledge as the essential guide to social policy.

It is hard to say which is more incongruous, the turn against modern science in scientifically advanced countries, or the same phenomenon in countries most urgently in need of scientific advancement. The global spread of the anti-science attitude has the potential to lead to social, environmental and/or economic disasters of unprecedented proportions.

In Part I, I briefly set out a significant social problem, global warming, that is exacerbated by anti-science ideologies, and I introduce the cultural studies of science education (CSSE). In Part II, I examine prominent post-modern theses commonly held in, and characteristic of, the field of CSSE. I argue that acceptance of these post-modern theses is antithetical to the development of genuine scientific knowledge, and to the application of scientific method and knowledge to urgent social/cultural crises. In Part III, I argue that there is a set of philosophical positions that is conceptually essential to the understanding of genuinely modern science, and antithetical to central CSSE theses. This set includes naturalism, ontological realism, a correspondence conception of truth, and a naturalistic conception of knowledge.[3]

[3] I shall use the term 'modern science' to indicate inquiries and the results thereof that conform to the philosophical/social norms of science. The term 'modern science' is used normatively, referring to science properly so-called.

4.1.1 Anti-science in Contemporary U.S. Culture

Recent news reports in the United States on global warming should be alarming to proponents of modern science. The scientific consensus on the human causation of global warming is well established. A comprehensive account of the scientific consensus is available, in Stocker et al. (2014). Despite the scientific consensus, anti-science ideology in the U.S. Federal government is politically influential. Major U.S. Federal House and Senate committees charged with deciding on issues of national science policy are led by politicians who reject the consensus of modern science, generally for religious reasons (see Bradley 2011). The position of Senator Jim Inhofe (R., Oklahoma) is an example. Inhofe is the Chair of the Senate Committee on the Environment and Public Works. Inhofe "has called climate change 'the greatest hoax ever perpetrated on the American people' and compared the EPA [Environmental Protection Agency] to the Gestapo" (2014 Nov 15 From the Economist, *Climate Change: Dealing with Denial*).

Donald Trump, while a Presidential candidate, provided another example. During an interview by the editorial board of *The Washington Post*, Trump stated:

> I think there's a change in weather. I am not a great believer in man-made climate change. I'm not a great believer. There is certainly a change in weather that goes—if you look, they had global cooling in the 1920s and now they have global warming, although now they don't know if they have global warming … Perhaps there's a minor effect, but I'm not a big believer in man-made climate change.[4]

Other highly placed deniers of human caused global warming include: Congressman Paul Ryan (R. Wisconsin), House Majority Leader; Senator Lisa Murkowski (R. Alaska), Senate Committee on Energy and Natural Resources; Congressman Fred Upton (R. Michigan), Chair, House Energy and Commerce Committee; Senator Mitch McConnell (R. Kentucky), Senate Majority leader; and Congressman Lamar Smith, Chair of the House Committee on Science, Space and Technology.[5] The anti-science attitude of corporate entities primarily concerned with expanding the wealth and power of the corporation, though deplorable, is not surprising. But it is surprising that voters in the U.S. would repeatedly elect persons with strong anti-science platforms to positions in the federal government. Cultural antipathy toward science is a troubling state of affairs, when the effective amelioration of current social problems is the overall goal. Though the causal factors contributing to the anti-science ideology are many and diverse, one point of intervention

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[4] https://www.washingtonpost.com/blogs/post-partisan/wp/2016/03/21/a-transcripteditorial board-of-donald-trumps-meeting-with-the-washington-post-editorial-board/

[5] For a fuller account, see Dunlap and McCright (2014), Merchant (2015), and also
http://www.joanneoellers.com/wp-content/uploads/2014/03/Republican-and-Democratic-Views-on-Climate.pdf
http://www.environmentmagazine.org/Archives/BackIssues/September-October 2008/dunlap-full.html
http://thinkprogress.org/climate-denier-caucus-114th-congress/ http://thinkprogress.org/climate/2013/12/11/3045841/house-science-hearing-weather-climate/

could be the science education efforts in the U.S. public schools. Yet current trends in science education, arising in the CSSE literature, are inconsistent with the nature of science, properly conceived.

4.1.2 Cultural Studies of Science: Re-conceptualizing Science and Science Education

Ken Tobin, in his 'Connecting science education to a world in crisis' (Tobin 2015), maintains that the global crises currently facing the world cannot be adequately addressed unless science educators adopt a new position on the logic of science, a position which Tobin calls "multilogicality". Tobin's multilogicality, intended to provide for openness to multiple and diverse cultural beliefs in the context of science education, seriously misconstrues the nature of modern science.

Tobin makes the claim that, currently, much of science education suffers from an outdated "adherence the tenets of crypto-positivism" (Tobin 2015), and that this creates problems for research in the social sciences.[6] For example, an "over reliance on statistical analyses leads to oversimplified modes that strip away context and are reductive…. Hypotheses and associated statistical tests support causal models that rarely predict social conduct…" (Tobin 2015).

In response to the inadequacies of what are conceived as positivistic scientific methods, Tobin develops the notion of "a multilogical methodology that embraces incommensurability, polysemia, subjectivity, and polyphonia as a means of preserving the integrity and potential of knowledge systems to generate and maintain disparate perspectives, outcomes and implications for practice" (Tobin 2015).

The stated aim of a multilogical method raises concern. Multilogical method is described as "a means of preserving the…potential of knowledge systems to generate and maintain disparate perspectives, outcomes and implications for practice…" (Tobin 2015). The project of acquiring an objective scientific knowledge of the world seems to be denied by Tobin. Tobin seeks to maintain disparity in beliefs about the world, and considers this state of confusion about the interactive dynamics of the world to be a good thing, and the goal of scientific inquiry. Why?

The answer seems to be Tobin's rejection of "power discourses". Tobin writes:

> In such a multilogical model, power discourses such as Western medicine carry no greater weight than complementary knowledge systems that may have been marginalized in a social world in which monosemia is dominant. (Tobin 2015).

The consequences of Tobin's re-conception of science can be dire. Consider, for example, its consequences in the current social crisis due to the spread of the Zika virus by the *Aedes eagypti* mosquito. Modern medicine (sometimes called "Western" medicine, despite its global range) has identified a connection between the Zika

[6] For an account of the all-to-common misconstrual of positivism in education writing, see Matthews (2004).

virus and the development in utero of microcephaly in infants. Alternative beliefs about this threat to health may arise from "ways of knowing" other than scientific inquiry. Unwarranted beliefs about the causes of the microcephaly epidemic will serve to exacerbate the crisis. Tobin, though, "accept[s] poly-ontology (i.e., the co-occurrence of multiple realities/many ways to answer the question: What happened?)" (Tobin 2015). While it is possible that many different and conflicting opinions about the causes of the Zika situation can be generated, it remains the case that the causal interactions that constitute the medical crisis are real, and can be known, in principle, via scientific inquiry. It should not need stating, at this point in the progress of modern science, that only inquiry that is conducted according to scientific norms has the potential to ameliorate the problem: at a given time there may be more than one scientific answer to the question, and all such answers will depend upon social and political support in order to be acted upon. But none of this is to say that *all* opinions on the etiology and means of transmission of the Zika virus are equally true or worthy of funding.

What are the conceptions of the nature of scientific inquiry and of scientific knowledge that are advanced in the theoretical literature in the cultural studies of science education? I will address this question next, and argue that the central philosophic theses underlying the cultural studies of science and science education actually undermine development of true beliefs about the nature, methods and results of science.

4.2 Postmodernism and the Cultural Studies of Science Education

4.2.1 The Postmodern World-View

The postmodern worldview presents numerous variations on its basic theses. I will set out several post-modern theses that are prominent in the context of science and science education.

In *The Reenchantment of Science: Postmodern Proposals*, Griffin calls for a "constructive post-modernism" that will reverse the disenchantment of the world wrought by modern science and scientific knowledge; this disenchantment is said to be due to "the denial to nature of all subjectivity, all experience, all feeling…" (Griffin, in Griffin, (ed.,) 1988b, p. 2). Harman (in Griffin, (ed.), 1988a) sets out "… the 'secret' [that] has been more and more openly shared: *Experienced reality does not conform to the 'reality' they taught us in science class; the 'scientific worldview' is not an adequate guide for living life or for managing a society"* (Harman 1988, p.122, emphasis in original). Harman calls for development of a "complementary science" that would "take as its particular focus subjective experience, consciousness…purpose, value choices, ...alternate states of consciousness, [and] particularly 'deep intuition'" (Harman 1988, p. 123), among a long list of other subjective mind-based foci.

Harman states: "Whereas the implicit assumption in positivistic science is that the basic stuff of the universe is matter-energy, this alternate approach makes a different assumption: *The basic stuff of the universe exhibits two fundamentally different kinds of properties: matter-energy properties and mind-spirit properties*" (Harman 1988, p. 123, emphasis in the original). The post-modern view Harman promotes returns to the substantial dualism of Descartes, a duality of Mind and Matter, somehow conjoined and interactive. This view is unsupported by modern science, and thus is counterproductive in the teaching of science.

Farrell (1996) takes a different tack, critically examining the historical development of post-modernism, and analyzing its radical departure from the world-view of the modern period. Farrell posits three potential sources of power that serve to determine the beliefs of persons. These are: (1) the world; (2) the self; and (3) the culture. According to Farrell, in a modern society, the principal determinative factor is considered to be the world (reality, what is). In a postmodern society the principal determinative factor is considered to be the culture (cultural practices, linguistic discourse, established beliefs). Farrell finds this change in emphasis to be the "standard move" in postmodern thought. Postmodernists emphasize culture as the determinative factor in fixing belief, and to such a radical extent that the other two factors largely drop out of the picture.

Farrell gives a number of examples of this, but one is particularly pertinent: "Did the scientist match his beliefs with what reality is like? No, says Rorty. He made his beliefs conform with what conversational practices had frozen as the background that fixed what everyone would count as real" (Farrell 1996, p. 249). For the postmodernist thinker, "all determinative power flows to the position of cultural practice and interpretation" (Farrell 1996, p. 249). Postmodernism is "inflating the role of cultural practices so radically that world and self virtually disappear as constraints on those practices or as measures of their success" (Farrell 1996, p. 249).

Farrell's description of postmodernism fits well with the thesis common in the CSSE literature that all forms of knowledge, and even scientific knowledge, are mere dogmatically held cultural beliefs; there is little if any place for the world in driving theory commitment or theory change; it is all a matter of intracultural negotiation. The culturally-set beliefs need not be subjected to the continual critique, via the experimental testing that is definitive of genuine scientific knowledge. In all cultures, the dissemination of knowledge is necessarily a matter of cultural products—e.g., books, journals, web sites, etc.—but, the process of achieving knowledge via ongoing scientific experimental inquiry distinguishes modern scientific culture from postmodern culture.

4.2.2 Re-constructing Science

The radical re-conceptualization of the concept of science and the subsequent reconstruction of science education are key intellectual aims of the literature that makes up cultural studies of science education. (See, for example, Irwin & Bednarz

(1998), Roth & Barton (2004), LaRochelle et al. (2009) and Sefa Dei (2011).) Roth et al. (2001) set out their view succinctly. "Science is viewed as a discourse that is a relatively recent activity of humankind, the goal being to make sense of a universe of phenomena in terms of knowledge that is viable" (Roth, Tobin & Ritchie 2001, p. 218).

Examined closely, this statement provides a great deal of information about the CSSE conceptualization of science. "Science is viewed as a discourse…". Science is conceived as a culturally based set of discursive practices that human beings sometimes engage in. The authors make no mention of the activity of experimental inquiry. The goal of a discursive science is "to make sense of a universe of phenomena". The authors make no mention of the discovery of real causal relationships existing among thing/events in the world, which determine the occurrent and possible interactions in a localized natural system. The goal of science, as described by Roth, Tobin, and Ritchie, is subjective; the goal is to develop ideas that make sense to certain persons, or, more broadly, to certain cultures. But, in the absence of the ongoing experimental testing characteristic of modern scientific inquiry, there is an endless number of different and mutually exclusive sets of ideas that might "make sense", subjectively, to different persons and cultural groups. Absent commitment to modern science, individuals and cultures can be expected to develop and accept radically different ideas about interactivities that constitute the universe. And, absent the commitment to modern scientific inquiry, with its acceptance of the fallibility of knowledge, demonstrably false beliefs are likely to be dogmatically held.

Roth et al. (2001) describe the universe as a universe of phenomena. The term 'phenomena'serves to indicate the presence of active meaning-making subjects whose interpretation of experienced events is in large part determined by their own conceptual structures, or by the culturally inculcated core beliefs. It is the subjects' experiences that must be made to make sense; the universe as it is in itself apart from the contribution of the experiencing subject is considered to be inaccessible. As such, it cannot be objectively known, nor even known to exist.

The concept of 'knowledge' appears in Roth, Tobin and Ritchie's conception of science. They specify that this knowledge is to be "viable", and make no mention of its needing to be judged to be true, or likely to be true, on the basis of compelling reasons. The concept of viability as the defining characteristic of knowledge is a thesis developed in von Glasersfeld's (1993) 'Questions and Answers about Radical Constructivism' where he writes "Truth in constructivism, as I keep repeating, is replaced by viability" (Glasersfeld 1993, p. 25). When knowledge is conceived as any belief-system that meets the criterion of viability, it follows that any longstanding, "time-tested" system of cultural belief must be counted as knowledge. As each culture has its own historically developed body of such beliefs, each culture has its own knowledge. The body of cultural belief, developed by any sort of method and tested only by its endurance over time, is to be considered, in the postmodern/cultural studies worldview, to be the "science" of that culture.

On this view, "science" is any process occurring in a culture that is causally active in developing the longstanding beliefs of the culture. It matters not what methods are employed to fix upon the body of belief that comes to be accepted by

the larger cultural community. The method of fixing belief could involve the retelling of traditional stories, or the study of revelations believed to reside in a sacred text. Or, the fixed belief may have come in a dream, or by intuition. All methods are to be held equally productive of "knowledge", in the sense of longstanding cultural belief, and therefore all are held to be equally "scientific", in the new sense.

In the CSSE literature, social justice is taken to require that long-standing belief systems of all cultures be respected equally as bona fide knowledges, particularly by the "Western" scientific culture. This is an odd requirement. It is motivated, it seems, by the idea that long-standing belief systems must be getting *something* right, given that the societies in question have persisted, "successfully", for very long time-spans.

Modern science, in contrast, is recognized to be a quite recent form of activity. And, because of the commitment of modern science to continual testing and revision of the body of knowledge acquired, both the methods of inquiry and the conclusions of inquiry are continually changing. The most current science of the present day is substantially different from the science of previous centuries. So, the criterion of "long-standing-ness" would serve to rule out modern science as knowledge. What is in fact the most advanced knowledge would thus be judged not to be knowledge at all. Yet, in the cultural studies of science education literature, calls are made for the inclusion of long-standing cultural belief systems and methods of "inquiry", in the science education classroom (see McCarthy 2014).

It is considered necessary in the CSSE literature to hold that there is a multiplicity of culturally based knowledges, many of which will be mutually inconsistent, and thus mutually exclusive, or would be, if the concept of correspondence truth were in the picture. It is clearly true that fundamentally different conceptions of the dynamic interactions of the world exist, in the various cultures and sub-cultures created by human beings. But the fact of culturally based epistemic diversity does not determine the cognitive value of the accepted conceptions of the world.

The CSSE pedagogical implication is that, in science education, a rich array of different knowledges should be offered in the classroom, from which each student may choose. The only criterion of choice, once a correspondence theory of truth is rejected, is that the chosen knowledge system either has utility for or makes sense to the individual; these are subjective criteria. It is quite likely, and understandable, that the familiar knowledge (belief-system) of one's culture of origin will be chosen over modern science. Such choices, it is held, must be fully respected, as a matter of an ethical obligation of respect for persons and for cultures.

Given the technological products of modern science, humans now occupy a globe in which travel has become relatively easy. "Border-crossing" between and among cultures, both literally and figuratively, is a common phenomenon. Different cultures, formerly geographically isolated, which may have historically developed different knowledges, values, and ways of living, are increasingly coming to occupy the same geographical regions. This can lead to assimilation, in which the cultural "borders" gradually disappear. But it can also lead to cultural conflict, which may develop into domination, exploitation, and violence, and even to attempts at cultural genocide. This state of cultural antagonism is one of the most serious of the dynamic

interactions facing global society, and may become catastrophically destructive. How is the problem of cultural conflict to be addressed?

In the post-modern world-view, and in cultural studies of science education, the solution is thought to require a radical change in the naturally human antagonistic response to cultural difference. An important goal of education, and *a fortiori*, of science education, on this view, is to bring about the appreciation and celebration of interpersonal difference. Two things are conflated, however: respect for persons, and respect for persons' beliefs. Respect for persons is an essential social ethical norm, a judgment that can be warranted by reference to inquiry into the well-being of persons in a social context. But this ethical norm does not require adopting a non-critical attitude toward the beliefs, practices, or knowledge assertions of those persons. Persons are to be treated with respect. In contrast, the actions, belief, and assertions of knowledge of all persons are to be subjected to ongoing critique, and continual testing, through modern scientific inquiry, for evidence of truth. Such critique is important if social problems are to be ameliorated; and, such critique is itself a form of respect for others as rational persons.[7]

Given the multi-logicality and multi-science commitments of CSSE curricula, students are likely to accept that making legitimate value judgments with respect to belief systems is not possible, and that efforts at evaluation are morally deplorable. This is a mistake. Comparative evaluative judgments of belief systems are possible, via scientific method (see Sect. 4.3).

Gellner identifies two approaches to the evaluation of socially accepted beliefs: re-endorsement theories and selector theories. Re-endorsement theorists "after profound reflection, reach the conclusion that all is well with [the] existing bank of beliefs, or at least with a substantial part of it, simply in virtue of it *being* the existing bank of beliefs" (Gellner 1974, p. 46). Gellner gives an example of a re-endorsement form of evaluation, built upon the principle of natural selection. The argument "could run as follows: beliefs only survive if true. Hence the bulk of time-tested beliefs of any society must be correct. Hence it is wrong to be doubtful of the whole bulk of local convictions. All in all, they must be sound" (Gellner 1974, p. 47). Re-endorsement theorists "claim to have found some reasons for supposing that current beliefs, simply in virtue of being part of the existing bank of ideas, are sound. No *outside* endorsement is required, they claim" (Gellner 1974, p. 47).

This is the reasoning that underlies the CSSE view of the assessment of claims to have knowledge. Gellner argues against such reasoning, and concludes that evaluation of the cognitive legitimacy of socially accepted banks of belief requires the selector theory approach. Selector theories:

> set up some *criterion*, some touchstone or sifter, which is to sort out the cognitive sheep from the goats. It is of the essence of this approach that the principle of selection claims to be independent of the current and local set of beliefs, to stand outside them and to be endowed with an authority external to that set (Gellner 1974, p. 47).

[7] On this issue of respectful disagreement see, among others, Siegel (1997).

Gellner give an example of a selector theory: “beliefs are sound in so far as they are arrived at by the methods of natural science, which consist of (let us say) accurate observation, and the acceptance of theories only if well-supported by such observations” (Gellner 1974, p.47). Gellner’s distinction captures the difference between the cultural studies mode of evaluation of bodies of belief and the evaluation of bodies of belief characteristic of modern science.

4.2.3 The “Sciences” of Culturally Distinct Peoples

The CSSE thesis of “multi-cultural science“, or, alternatively, “multi-science”, is problematic. One problem with adopting this re-construction of science is that the move is thoroughly destructive of the communicative usefulness of the term ‘science’. This is because when a term is given an extension that includes radically different and mutually exclusive activities and things/events in the world, the term loses its meaning. It can no longer serve to refer to some *particular sort* of thing/event, nor can it indicate a particular meaning to other persons. The term loses its intellectual function of marking a particular concept that has a place in a logically connected network of meanings.

It might be argued that this is a mere inconvenience, easily remedied by systematically qualifying the term ‘science’—e.g., to speak of “modern Eurocentric science” and contrast this science with any number of culturally specific sciences, e.g., indigenous Blackfoot science, or indigenous African science. But this misses the point. If “science” is the overarching linguistic/cultural category, its subcategories should share features in common that mark them as forms of the broader category of science. When there are fundamental differences in meaning of the subcategories, the meaning of the term ‘science’ is attenuated to the point of near vacuity. Once the extension of the term ‘science’ is accepted, the body of religious dogma of various Christian fundamentalists can legitimately be called “creation science”, even though there is nothing in the methods of inquiry that qualifies this body of religious belief as a science.

The term ‘science’ has long served as a technical term with a specific meaning. With the cultural studies of science education’s revision of the meaning, we now have two mutually exclusive alternative meanings, the standard meaning, and the cultural studies of science education meaning. The CSSE reconceptualization brings to the term ‘science’ an indefinitely large number of possible specific meanings. The term ‘science’ has been associated in the cultural studies usage with so many fundamentally different specific meanings that, to be useful at all, the term must be qualified. I will use the term ‘modern science’ to mark one conception of science, and the term ‘post-modern science’ to mark the indefinitely ambiguous re-conception developed in the cultural studies of science education field. The same point applies to the term ‘knowledge’; it is necessary to distinguish “modern scientific knowledge” from other forms of “knowledge” that are claimed, e.g., beliefs one accepts on the strength of dreams or scriptures, etc..

The CSSE re-construction, along with the adoption of a re-endorsement approach to evaluation of cultural beliefs, brings an evaluative relativism to the classic demarcation question in the philosophy of science. The demarcation question asks, by what criteria is genuine science to be distinguished from pseudo-science, from non-science, and from just plain nonsense? With the cultural studies conceptual innovation of multi-science, and more recently, multi-logic, the demarcation question is abandoned. In the cultural studies of science education, there are no criteria that allow the demarcation of modern scientific inquiry and knowledge about the dynamic causal inter-relations in the world from culturally accepted belief-systems that are inconsistent with modern science.

4.2.3.1 Indigenous Knowledges

Modern science, which is often said to have begun in Europe, (a view which disregards the myriad outside cultural influences on European cultural development) is considered in the cultural studies of science education to be a form of thinking that is deeply alien to persons of non-Western cultural origin. This diverse group includes all indigenous peoples,[8] and all persons of a non-European, non-Caucasian ancestry. It includes even "indigenous" persons and persons of non-Western ancestry who were born, raised, live and/or work in Western cultures. (See McCarthy 2014, p. 1938–1946.)

This is the thesis of cognitive essentialism. The assumption of this thesis is that human beings are *essentially* different, constitutionally different, from one another, in many ways, but in particular with respect to cognition and affect. There are thought to be "different ways of knowing" that are characteristic of distinct subclasses of the general biological category of *homo sapiens*. In the cultural studies view, the cognitive/affective differences are not merely culturally learned, and thus familiar, ways of thinking, feeling and valuing. These differences are genetically inherited, due to the long-standing cultural isolation of certain peoples. But this is a belief that is not warranted by modern science.

The thesis is, moreover, morally odious. The practical consequences of widespread adoption of and action on the thesis would be harmful, in major respects, to those persons deemed to be culturally and/or constitutionally ill-suited to the study of modern science. The science education offered to non-Caucasian persons would be limited by the perceived need to provide a culturally relevant curriculum, one that incorporates the culturally accepted beliefs—the "knowledge"—of each person's culture. This would have the further effect of denying to non-Caucasian persons equitable access to participation in science-based economic and cultural opportunities. The differentiation of science education curriculum would also likely

[8] The meaning of the term 'indigenous' is conveniently left vague, so much so that the term can be applied to virtually any group of people. The connotation is that indigenous peoples somehow belong to a particular geographical area, by virtue of having occupied that area in relative isolation, from time immemorial.

have deleterious effects on the self-conception of those who arset out their view succinctlye provided with "special" science education. The "multi-science" curriculum, promulgated as a special benefit, designed to assist the non-Caucasian student to understand and to be able to function within the constraints of "Western" modern science, is actually a particularly detrimental form of crypto-racism.

But it is clear that this is the position generally accepted by scholars in the cultural studies of science education field. For example, Elmesky (2011) takes it as given that persons of African ancestry, even those whose families have been long resident in cultures advanced in the practice of modern science, are alienated on a fundamental level from the patterns of thinking that characterize modern science.[9]

In *Theory of African Metaphysics,* Nichodemus provides details about the supposed "African" way of knowing. It is inconsistent with modern science. The author focuses considerable attention on the African commitment to the principle of causation. And gives a chilling example:

> In the African context, when the African asserts that the witch has killed her (the African) child what she is merely asserting is that the death of her child is an effect traceable to a cause in this case, the witch. The African understands that there must have been contact between her child and the witch. This contact is believed to be metaphysical. Among Africans, it is widely believed that the witch makes her contact by the help of an "invisible" rope…only the 'gifted' or the 'seers' can see this invisible rope used by witches. (Nicodemus 2013, p. 71.)

Nichodemus quotes Omoregbe (1990), to generalize the African causal principle: "There is no action without a cause, and the cause is always an agent or some agents utilizing some forces" Nichodemus 2013, p. 108). African philosophy involves the rejection of modern science. It is, she writes,

> a fundamental error of modern science, which is at the basis of modern medicine to assume that it has a comprehensive grasp of all that there is in reality, so it can state that whatever is not analyzable and explicable by its standards is not real or does not exist. (Nichodemus 2013, p. 109).

The African healer is reported to have access to important other ways of knowing, that go beyond the evidence of the sensory mode, and into the clairvoyant mode, where telepathy, clairvoyance and precognition are the principal means of divination. (Nichodemus 2013, p. 110). The author's use of the term 'African' makes it clear that every person native to the continent of Africa, who is raised in a traditional community, is taken to share the same cognitive stance.[10]

It is asserted that the incompatibility of modern science with the ways of thinking, being and doing of Indigenous peoples is so severe that to teach modern science to these peoples can constitute a form of intellectual colonialism. "[I]n many educational settings where Western modern science is taught, it is taught at the expense of indigenous science, which may precipitate charges of epistemological hegemony and cultural imperialism" (Snively and Corsiglia 2001, p. 7). Avoiding such charges

[9] For similar views, see Meyer and Crawford (2011), Ogawa (1995 and 1998), Roth (2009), Sefa Dei (2011) and Ritskes (2011).

[10] See also Metallic (2009).

while teaching modern science would be difficult, since Snively and Corsiglia follow Ogawa's (1995) view that "every culture has its own science", which is the culture's indigenous science (Snively and Corsiglia 2001, p. 7). I will examine below several representative examples of the belief-systems of Indigenous peoples, in the process of revealing the inconsistency of those belief systems with the knowledge resulting from methods of modern scientific inquiry.

Pavlik (2014) provides a thorough explication of the orthodox traditional cultural belief system of the Navaho people. His account, he states, is vouchsafed by Navaho traditionalists, and arises from Pavlik's 19 years of immersion in the Navaho culture, as teacher and student and participant. The orthodox traditional Navaho knowledge system, according to Pavlik, derives from a time before contact with outside cultural forces and Judeo-Christian religions. Drawing on early anthropological research, Pavlik writes that "It was a time when the Navaho people followed only the teachings of the 'Holy People', the *Yeis*. It was a time when they saw themselves intimately connected to, and part of, their sacred land and the other living beings with which they shared that land" (Pavlik 2014, p. 7).

Pavlik describes his work as "a study in the traditional [ecological] knowledge (TEK) of the Navaho people…how they viewed the natural world, their relation with the Animal People, and very specifically, with carnivores or predators" (Pavlik 2014, p.15). Pavlik quotes Berkes' (1999) definition of TEK; it is the "'cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and their environment" (Berkes 1999, p. 8, quoted in Pavlik 2014, p. 15). Pavlik distinguishes the traditional Native American relationship with all living things from that of western society: "Unlike western society, whose relationship with all life is based on competition and exploitation, the tribal relationship with all life—including the Animal People—was based on cooperation and reciprocal exchange" (Pavlik 2014, p. 15).

According to Pavlik, Navaho TEK has two forms: "the sacred (spiritual) knowledge handed down to them through the creation stories, and the experiential knowledge acquired through centuries of observation, inventiveness, and practice" (Pavlik 2014, p. 16). The creation stories are attended by a strong emotional component, which gives rise to the Navaho ethical system. Pavlik writes that TEK is gaining attention in western society, but that "[i]n general, the western scientific community continues to dismiss or disparage indigenous wisdom"(Pavlik 2014, p. 16). This rejection of TEK by western scientists occurs "because it is often not 'testable' in the scientific sense"(Pavlik 2014, p.17), and because "western science steadfastly tends to not take seriously any spiritual knowledge—the foundation of TEK." (Pavlik 2014, p.17).

Pavlik asserts that the Navaho have always known what is just now being discovered by modern science in the field of cognitive ethology, that animals have emotions and thoughts. The traditional knowledge of cognitive ethology, though, differs from that of modern science. "The fact that Navaho TEK stems from the sacred creation stories—from the spiritual realm—distinguishes it from mainstream cognitive

ethology that accepts only a scientific evolutionary cause for animal behavior." (Pavlik 2014, p. 19).

It is clear, from Pavlik's account of TEK, and from the traditional stories and beliefs collected and discussed in the text, that TEK is based upon a tradition of divinely given stories, passed down through the generations. These sacred stories were used to provide interpretations of the meanings of the relations of the Navaho with the world they experienced. This store of divinely given statements stands as the set of foundational, indisputable statements, which are believed to constitute a foundation that justifies further knowledge claims. (See also Ritskes (2011) on the inclusion of Indigenous spirituality in science education.)

Deloria sets out the Native American world-view in great detail (Deloria 2002, 1997), and stresses the Native American concept of "power", as a spiritual living energy that pervades the universe. Pavlik (2014) follows Deloria in this, writing "The Navahos have long known that the universe is spiritually alive. *Everything* is a living breathing, spiritual entity. Every mountain and river, for example, possesses a spiritual essence" (Pavlik 2014, p. 45). Moreover, "The Navahos also know that there are wholly spiritual beings that reside at these places and protect them. The Navahos refer to these energetic entities as the *Yeis*, or the Holy People" (Pavlik 2014, p. 460).

It should be clear that dogmatic acceptance of traditional spiritual beliefs, derived from stories taken to be sacred, has nothing in common with the methodological norms of modern science. The case is the same as for the current fundamentalist Christian beliefs in young earth creationism. In each case, the belief system is religious dogma, not scientific knowledge. If scientific knowledge is understood as a set of statements that is well-warranted by evidence acquired via a rigorous process of experimental inquiry (as I shall argue in Part III that it should be), then the traditional spiritual beliefs that largely comprise TEK do not count as scientific knowledge.

The mixing together of the immutable doctrines of religious belief systems with the fallible results of modern scientific inquiry, held subject to continuous critical examination and testing, creates a serious problem of intellectual coherence, because the two world-views, the scientific and the religious, are incompatible in fundamental respects.

Mahner and Bunge (1996) argue that science and religion are factually, methodologically, attitudinally, ethically, and metaphysically incompatible, and that science education and religious education are, as a corollary, incompatible. Mahner and Bunge's analysis provides clear criteria that separate the religious from the scientific. Even a cursory inspection of the contents of what are said in CSSE circles to be systems of "indigenous science" reveals that the belief systems in question are religious, and bear no relation to science. "[I]f one is concerned with the education of the public, then the teaching of the religious attitude and value system can only have detrimental effects for adopting a comprehensive scientific outlook or critical attitude" (Mahner and Bunge 1996, p.118).

Peat, in *Blackfoot Physics: A Journey into the Native American Universe* (2005) asserts that modern science deals only with what can be measured and treated math-

ematically, and thus excludes from reality such things as love, beauty and mystical ecstasy, and is therefore problematic. Peat asserts that there is an alternative way of thinking about the world, an indigenous science that is distinctly different from modern science. Peat states: "Indigenous science does not need to explain itself to anyone. It has no need to compare or authenticate itself against the standard of Western science" (Peat 2005, p. 241). In comparing the "two sciences", Peat argues first that modern science does not live up to its own standards. Peat notes, correctly, that modern science is supposed to be guided and arbitrated by nature, but then asserts, incorrectly, that "scientific theory is supposed to stand or fall according to the results of a single critical experiment" (Peat 2005, p. 242).

Recounting the Pons and Fleischman experimental efforts to demonstrate cold fusion, and the negative reaction of the scientific community to their claims to have done so, Peat asserts that "far from all experiments [are] reproducible…it is well known that some individuals can get a particular experiment to work, while others never will" (p. 246). Peat concludes, "Hence, the very basis of science, its objective, repeatable, quantitative observations and experiments, is an unattainable ideal, for the way scientists are able to design experiments and carry them out is influenced in so many subtle ways by their feelings and sensitivity to the complex universe around them" (Peat 2005, p. 246).

Peat's implication is that certain persons are more attuned to the universe, in a direct, personal, spiritual way, and this special relation enables such persons to achieve experimental results that are not possible for ordinary persons. It is Peat's view that modern science is a cultural product of the West, and as such is merely one human response to the world, one science among many other sciences that are equally legitimate, or perhaps more legitimate. "The fact is that Western science, and the way we pursue it, is a product of our value-system and our worldview. Societies with other values and other worldviews may choose to carry out their science in radically different ways" (Peat 2005, p. 248). But, *contra* Peat, the development of modern science is in fact a global accomplishment, both now and in its historical development. To treat modern science as if it were an ineluctably culture-based belief system, just one among many other equally valuable "ways of knowing", is not justified.

In *Blackfoot Physics*, Peat is explicit about the nature of Blackfoot cultural belief system, and makes it clear that that belief system is fundamentally inconsistent with the belief system warranted by modern scientific inquiry. Peat also makes it clear that the methods of fixing belief in Blackfoot culture are incompatible with the method of modern scientific inquiry. Moreover, according to Peat, the Blackfoot epistemological model and worldview is representative of all indigenous belief systems. Peat sets out 29 major ways that Indigenous belief systems and methods differ from those of modern science. A few quotations with respect to key differences will have to suffice to indicate the incompatibility that Peat quite effectively establishes.

Objectivity "If objectivity implies the ability to abstract and distance oneself from nature, then this is definitely missing within Indigenous science. In its place, however, stand consistency, integration, harmony and balance" (Peat 2005, p. 255).

According to Peat, in Native science, "stress is laid upon direct subjective experience and upon closeness to nature. The powers, energies, and spirits of the world are personified to the extent that it is possible to enter into direct relationship with these elements and negotiate pacts, compacts and ways of living together with them" (Peat 2005, p. 255).

Prediction "The concept of what, within Western science, would be called prediction is profoundly different within a metaphysics that is not based upon the notion of causality….There is a sense in which dreams can have a predictive quality…the dreamer is not confined to a single present but can move back and forth along the curve of time" (Peat 2005, p. 255).

Experiment Peat states: "Analogies can be drawn between…contemplative practices of the East and the observational/experimental approaches of Indigenous science. So, while Indigenous science does not employ experiment in the Western scientific sense, it does employ a disciplined approach to merging horizons with the inner reality of the world and revealing its different levels of process" (Peat 2005, p.252).

Observation "For observations to be of use they must be recorded and passed on… [in Indigenous cultures] knowledge is generally passed on through markings on rocks, mnemonics, songs, ceremonies, practices, artifacts and such things as earthworks. In particular, much knowledge about the world is enfolded within traditional stories" (Peat 2005, p. 250).

Control "Although it could not be said to be a form of control in the Western sense of the word, Indigenous peoples are also able to make use of certain processes in order to bring about desired effects … Examples include the ability to heal and to extract diseases from the body, or to negotiate with clouds in order to produce rain. Songs could also be thought of as processes, or scientific instruments, that bring about certain effects" (Peat 2005, p. 254).

Instrumentation In Indigenous science "knowledge goes beyond what can be apprehended through the normal senses…ceremonies and practices such as fasting, acts of sacrifice, dancing, ingestion of various preparations, dreams and visions all serve to refine the instruments of perception and allow direct contact with extended realms of reality" (Peat 2005, p. 260). "Indigenous science also makes use of technological instruments. For example, the Cherokee people utilize crystals in many different ways. One is in the preparation of medicine, where sunlight is guided through the crystal and onto the preparation to potentiate its power" (Peat 2005, p. 260).

Truth According to Peat, "Western science seeks ultimate truth, for it believes in a rational universe that can be understood by experimentation and reason….Truth in Native science is of a very different order. Truths…depend on tradition and social and spiritual sanctions. Dreams and visions are systems of validation. Truth is contained within origin and migration stories, songs and ceremonies…the source of truth is found in nature and in the direct experience of individuals through dreams and visions; conversations with rocks, trees, and animals; and patient observation of the world around them" (Peat 2005, p. 265).

Spirit and Energies "The animation of nature and the energies or spirits that reside in plants, animals, rocks and trees are characteristic of Native science. The acknowledgement of powers and the renewal of alliances through a variety of ceremonies also play a key role in Native Science. This notion of spirit, or numinous energy, is missing in Western science" (Peat 2005, p. 271).

Observer-Created Reality "The transforming, animating energies of Western science are strictly impersonal and move according to the objective laws of physics. These laws are pictured as being totally indifferent to human wishes and desires" (Peat 2005, p. 285). "In contrast, the Indigenous world is alive….Far from being indifferent to the existence of humans, it is possible for The People to negotiate with the world of spirits and form alliances with the powers that animate the universe. As an example, when drought occurs The People may carry out a rain dance." (Peat 2005, p. 285).

In this uncommonly detailed account, Peat makes it abundantly clear that the indigenous belief systems he describes are fundamentally inconsistent with modern science. The illusion of compatibility is created by nothing more than an extended trick of verbal magic. The terms that carry a specific technical meaning in modern science are lifted from the modern scientific context, and are applied to certain elements of the traditional Indigenous systems of belief and methods of fixing belief. But, in the new context, the borrowed terms no longer *mean* what they meant in the original context. So, for example, the meaning of the term 'observation' in the context of modern experimental inquiry entails empirical observations--persons noting events in the natural world, and especially, the events that occur following intentional interaction of person and environment. In the context of indigenous culture, the term 'observation' is used to include experiences that are had during sleep (dreams) or in altered states of consciousness (visions). This difference in meaning is glossed over; it is stated that both ways of fixing belief employ "observation", therefore both systems are equivalent in this respect. But, clearly, both systems in actuality rely upon quite different forms of practice.[11] The missing feature in all of the proposed "alternative sciences" is the scientific method itself.

Aikenhead and Ogawa set out "three diverse cultural ways of understanding nature: an Indigenous way…a neo-indigenous way…and a Euro-American scientific way (Aikenhead & Ogawa 2007, p. 539). The intent is to "better represent each culture's collective, yet heterogeneous, worldview, metaphysics, epistemology, and values" They also attempt to show that Indigenous knowledge systems share important features with scientific knowledge systems, namely, "empiricism, rationality, and dynamic evolution" (Aikenhead and Ogawa 2007, p.539).

[11] For further explanations of the nature of "Indigenous science", and calls for the inclusion of such science in science education, see: Aikenhead (2001), Boyer (2010), Cajete (2000), Deloria (1997, 2002), Langdon (2009), Medin and Bang 2014), Meyer and Crawford (2011), Ogawa (1995, 1998), and Snively and Corsiglia (2001). In 2017 there is a proposal before the U.S. National Association for Research in Science Teaching (NARST) to include Traditional Ecological Knowledge as a research strand in the organization.

Aikenhead and Ogawa define the term 'science' as: "*a rational empirically based way of knowing nature that yields, in part, descriptions and explanations of nature"* (Aikenhead and Ogawa 2007, p. 544). They follow Elkana (1971), in defining rationality as culturally relative, and explicitly reject any sense of universalist rationality. They take *perceiving* to mean "both the process of constructing what is perceived to be reality through the participation of a group of people, and their resultant mental constructions of reality" (Aikenhead and Ogawa 2007, p. 543). Further, they adopt "a multi-science perspective" (Aikenhead and Ogawa 2007, p. 544).[12]

In modern scientific inquiry, suggestions as to possible meanings can arise from any source, even from a dream or a trance. But, regardless of their origin, it is *de rigueur* in modern science that suggested meanings be subjected to a continual process of empirical, experimental testing, by a global community of scientists. The scientific testing of the suggested meanings is the key characteristic distinguishing science from fanciful non-critical belief.

Shahjahan and Haverkos present Indigenous systems of knowledge as instances of "spiritual epistemology", and argue that the academy unjustly takes knowledge to require a Eurocentric secular epistemology. The academy thus serves Western colonialism, unjustly fencing out all spiritually based systems of knowledge. "In the secular epistemological vision, rationality, anthropocentrism, and empiricism are lauded over many other ways of knowing (e.g., emotions intuition, metaphysical, and ancestral connections) (Shahjahan and Haverkos 2011, p. 377). Shahjahan and Haverkos argue that the dominant secular epistemology must be resisted, that the academy should accept spiritual epistemologies, and the "other" ways of knowing the world, as equal to modern naturalistic science in value. Ritskes goes a bit further: "In the Western academy there is currently no use for this kind of knowledge which flies in the face of everything that it stands for" (2011, p. 417.) While this should be true, it is apparently not true in the CSSE conception of science education.

Those who call for the inclusion of Indigenous "ways of knowing" in science education classrooms would seem to be either uninformed as to the actual substance of the body of belief that they extoll, or lacking in an understanding of the distinctive character of scientific inquiry and of scientific knowledge. But, it is also possible that advocates of inclusion of Indigenous "science" in science education are indeed aware of the difference, but for some reason are antagonistic to modern science and seek to "re-enchant" the world with the introduction of ancient, and still occurrent, superstitions.[13] In any case, the results of the infiltration of science education by this and other forms of anti-science can only have deleterious effects on the already poor public understanding of scientific knowledge, and the public dispositions to use scientific knowledge in addressing critical social problems.

Critical social problems are undeniably present. The problem of global climate change is one example, but it is drawn from a large array of such problems. That

[12] See also Aikenhead (2014).

[13] See Griffin 1988a, b.

global warming is occurring, and that it is one of the consequences of human interaction with the environing conditions, is well established by the community of modern science.[14] Given the vast number of causal conditions, among which one must include global human activities, that together constitute the conditions of occurrence of global warming, there is a pressing need to employ scientific knowledge of the dynamics of interaction in the natural world so that successful mitigation practices might be begun.

But, a shared societal consensus on the necessity of modern scientific knowledge is difficult to achieve, and becomes more difficult to the extent that science educators teach that traditional indigenous belief systems, and other alternate ways of knowing, are the cognitive equivalent of modern scientific knowledge. When, in the U.S., politicians facing drought conditions lead public rain dances, or public prayers, the causal conditions for climate catastrophe are enhanced.

4.2.3.2 Seeking Alternatives to the Scientific Way of Knowing

The claim that Indigenous cultural systems of belief are acceptable as alternative forms of knowledge for the science classroom is, on inspection, implausible. But additionally various other ways of knowing, also in opposition to the way of modern scientific inquiry, are commonly promoted in the cultural studies of science literature.

One prominent thesis, developed in the field of feminist epistemology, is that there are natural female ways of knowing, which are different in kind from the ways of knowing of males. Science, on this view, having been (largely) developed by male persons, is well fitted to the thinking patterns of males but is significantly less well suited to female persons. Science education, it is concluded, should, for the sake of social justice, incorporate the distinctive "women's ways of knowing". But to do so would require a radical reconstruction of the practices and theses of modern science.[15]

It is sometimes claimed that modern scientific inquiry is fundamentally alien to *all* persons, which is thought to explain why it is difficult for all persons to learn modern science; this thesis is sometimes used to justify calls for the re-enchantment of the world. Curiously, this is the least objectionable position. Peirce (1986/1878) famously noted that, for most people, it is not true belief that is actually desired. What is desired is simply the *fixation* of belief, which puts to an end the onerous process of thinking about beliefs and evaluating them with respect to the evidence of their being true. Wolpert, in *The Unnatural Nature of Science* (1992), argues that the way of thinking of modern science does not come naturally to people. To acquire the way of scientific thinking, an extensive period of science education is required by all. It is to be expected that to become adept in scientific thinking is difficult. But

[14] See Cook et al. 2016.

[15] For affirmations of this view, see Harding (1996) and Brickhouse (2001); for critiques of it, see Landau (2008) and McCarthy (2014).

this does not mean that the meaning of science should be changed to include within "science" the ordinary human approaches to fixing belief. It instead underscores the need for a science education that engages the students intellectually, and that helps them to develop a disposition to think scientifically.

The charge of "scientism"is frequently brought against modern scientific inquiry. The term 'scientism' can be defined as the belief that the methods and norms of modern science should be brought to bear on a wide range of problem situations, as the only legitimate means of attaining genuine knowledge of the real thing/events that constitute the problem. It is held that only through modern scientific inquiry that understanding of the dynamics of the problem situation can be attained. And it is only through modern scientific inquiry that effective means of ameliorating the situation can be devised. On this view, modern scientific inquiry should be applied to social, moral, political, economic and educational policy, in order to provide the best possible knowledge of such problems.

But scientism is also widely understood as a deplorable over-reaching of modern science, as an inappropriate intrusion of science into humanistic realms. Modern scientific inquiry is considered inappropriate, ineffective, and, indeed, strongly counterproductive when applied to the domain of human concerns. Smith (2013), for example, condemns scientism on the grounds that it conflicts with and undermines the ancient wisdom of religious revelations. "It is no wonder…that this presumed scientific wisdom runs aground when it comes to the understanding of man himself; that it has in fact shown itself categorically incapable of accounting for even the most rudimentary act of cognitive sense perception, let alone for the higher modes of sensory and intellective knowing" (Smith 2013, p. 10).[16] Rescher concludes "no matter how far we push science forward along the physical, chemical, biological, and psychological fronts, there are issues about humanity and its works that will remain intractable by scientific means … because these issues lie outside it" (Rescher 1999, p. 244–245).

Williams states "that scientism entails a metaphysical commitment to a naturalist, reductive, or emergent materialism and tries to define science in a way that includes not only a commitment to empirical methods, but also to this particular metaphysics….the propriety of any method is evaluated primarily in terms of whether it deals with the world as if it really is as naturalist materialist metaphysics claims it is" (Williams 2015, pp. 3,4).

Williams acknowledges that the methods of naturalistic and materialistic science "seem relatively compatible with the natural world" (Williams 2015, p. 8). Williams believes a problem arises, though, when such methods are applied to the human world. To do so would be to explain the fundamentals of human being "in terms of things outside of themselves, and to explain them in that way is to destroy them" (Williams 2015, p. 8). What Williams fears will be lost, it seems, is the conception of a uniquely human spirituality, that is outside the bounds of the natural materialistic world.

[16] See also Nagel (2012) and Sorell (1994).

But, the general method of modern scientific inquiry is the only way of providing the strong warrant for the truth of a proposition that is necessary for knowledge. Because human beings are themselves dynamic, interactive thing/events in the world, a part of the natural world, as are the social/cultural products of human interaction, a genuine knowledge of their interactivities is possible via scientific inquiry. There is no alternative way to acquire knowledge about the world. Bunge conceives scientism as "methodological realism", the thesis that "[t]he best strategy for understanding the world is the scientific method" (2006, p. 30), and links scientism to both scientific realism and materialism (2006, p. 280). This triad is the core of Bunge's *scientific hylorealism*, a position which, like Dewey's view of scientific inquiry, indicates the possibility of a science of ethics and social justice, generating knowledge in the sense of well-warranted assertibility.

4.2.4 Constructivism and Scientific Knowledge

Michael Devitt (2012) describes constructivism in this way: it is the thesis that "scientific entities are not independent but are somehow 'constructed' by the theories we have of them. This 'constructivism'has its roots in the philosophy of Kant and is extremely influential" (Devitt 2012, p. 101).[17] This ontological constructivism is widespread in education.[18] John Staver, a prominent science educator and constructivist, stated it as follows:

> …For constructivists, observations, objects, events, data, laws, and theory do not exist independently of observers. The lawful and certain nature of natural phenomena are properties of us, those who describe, not of nature, that is described. (Staver 1998, p.503)

Tobin and Tippins, in 1993, present constructivism as an epistemological thesis that has skeptical implications, but that does not deny that the world in all its interactions exists. "[T]he existence of a reality is acknowledged from the outset. What constructivism has to say about that reality, however is that we can only know about it in a personal and subjective way." (Tobin & Tippins 1993, p. 3). Tobin and Tippins give an example: they acknowledge that gravity exists, but assert that human beings can only come to know about what gravity *is* by individual personal experience of the phenomenon, supplemented by a social process of negotiation of meaning. Through social negotiation, they continue, "agreement is reached within our social system that the concept of gravity has numerous verifiable properties. We construct a model of gravity that is viable in that the model fits experience" (Tobin and Tippins 1993, p. 3).

But Tobin and Tippins explicitly deny that the model can be considered "to be an absolute truth"(Tobin and Tippins 1993, p. 4). They do not make clear what the conceptual distinction might be between "absolute truth" and truth *simpliciter*, truth

[17] See also Devitt (1991)

[18] For examples and discussion, see Matthews (2015, chap. 8).

as the correspondence of statements of interactions in the world with actual interactions in the world. It is possible that they use the term 'absolute truth' to refer to statements claimed to be indubitably true. But no modern scientist makes claims about scientific truth in the sense of indubitable truth, because scientific knowledge is understood as fallible, and only to be held subject to further evidence that brings the knowledge claim into doubt.

In Tobin and Tippins' view, knowledge begins with a subjective interaction, not with the real world, but with our constructions of the world. "Our constructions are constrained by experiences, which comprise subjective interactions with the real world as we have constructed it" (p. 4). If the term 'constructions' denotes imaginative conjectures about interactive events in world, this is a reasonable account of an early phase of every modern scientific inquiry. Our conjectures are imaginative. But, Tobin and Tippins seem not to notice that our experiences, i.e., our interactions in the world, are fully objective. That is so because the organism, including all its internal interactions, is no less a real interactive thing/event than is an inorganic interactive thing/event. We develop conjectures about the world, and expectations about the effects of our interactions with the world. But what we interact with is the world *as it is*, not the world as we have "constructed" it imaginatively.

Given that our interactions are objective real events, we can learn about the world by taking actions based on our conjectures about the world. Should our expectations about the observable state of the world following those actions be disappointed, we have learned that something is wrong in our conjectures about the world.[19] The hypothesis has been put to the test, and has been disconfirmed. Disconfirmation, in Popper's view, is strong evidence that our "construction" is not right, that it is false, in that it does not correspond to the world.

But, what about evidence of a positive sort? What if after action guided by a hypothesis we do observe the state of the world we had expected? Given severe testing of the hypothesis, the failure to observe disconfirmation, according to Popper, provides corroboration for the hypothesis. Corroboration is a matter of the appraisal of the hypothesis, and is a matter of degree. A hypothesis can be judged to be highly corroborated, or less well corroborated, by a scientific inquiry process (Popper 2002, p. 264–265).

Tobin and Tippins continue: "Since there is no objective account of what gravity really is, we cannot tell whether our model for gravity gets closer and closer to an absolute reality…we can only know gravity in a personal, socially mediated way." Tobin and Tippins seem to be supposing that an objective account of the actual workings of gravity must be available, *independent of human inquiry*, to which the results of human inquiry can be compared for accuracy. Something like a teacher's answer book. Since, obviously, there is no such extra-human account – because accounts of thing/events are all of human origin – there is no possibility of comparing one's conjectured account of gravity, or any interaction, to some imaginary "given" extra-human account. Though some persons purport to have received

[19] Or, that something is wrong with our background assumptions, or our experimental procedures, or our instrumentation, etc..

authoritative extra-human accounts of the world from a putative divine source, the evidence for this is underwhelming.

But, there is no need for such a pre-existing account, since what we do have is the actual world with which to interact. Popper's account of the logic of scientific discovery allows for both the disconfirmation of theories, and for the corroboration of theories, through experimental inquiry. As long as one is willing to discard the conception of knowledge as entailing absolute certainty of truth, no problem arises. Through interaction, designed to subject hypotheses to severe testing, we have the resources needed to assess the claim that the judgments reached about the world are true.

It is true that, initially, prior to cognition, we *experience* our interactions in the world in a direct, and qualitative way. But this primary qualitative experience, because it *is* immediate (i.e., unmediated by thought) and qualitative, is not knowledge. Achieving knowledge requires considerable cognitive mediation. It requires well-tested processes of testing prospective beliefs via active experimental inquiry.

The practice of modern science does have a social aspect; scientific inquiry must be associated with a cultural milieu that supports the search for true belief about the world through experimental inquiry into the puzzles, the "problem situations" that arise. The scientific search for knowledge, for well-warranted beliefs about the world, requires a cultural commitment of resources to the maintenance of a community of scientists, who will be working collaboratively over an extended period of time on the development of theories about the world, and the experimental testing of those theories. Modern scientific knowledge is a set of well-warranted judgments that result from the collective and continuing social process of scientific inquiry.

Truth is conceived in the cultural studies of science education literature as a matter of viability, either in von Glaserfeld's sense of holding up in practice, or in the broader sense of being culturally accepted over long periods of time. But, the simple persistence of belief over time is not a reliable indicator of the probable truth of the belief. Conceiving truth as a matter of a correspondence between statements about the events of the world and the actual events of the world, scientific inquiry allows the development of a set of theoretical statements about the world that are well warranted to be true.

Tobin and Tippin's epistemological constructivism is deeply embedded in the cultural studies of science education field. It is this position that supports the acceptance of all culturally established[20] belief systems as equally legitimate knowledge. This leads to the conviction that all cultures have their own forms of science, and then to the notion that all cultural belief systems must be equally respected, and equally welcomed, and for some, equally affirmed in the science classroom.

[20] In the cultural studies of science education literature, the cut-off date for "long-standing" belief is never specified, leaving the notion empty. Moreover, the age of a set of beliefs is entirely irrelevant to the truth of the belief, and is equally irrelevant to the warrant of the belief to be true.

4.2.4.1 Social Justice and CSSE

It is difficult to see why anyone would seek to acquire knowledge, in the post-modern/cultural studies sense of the term. It is certainly *possible* to alter the meaning of the term 'knowledge', in such a way that any system of belief about the dynamic interactions of the world will count equally as knowledge. But what will have been gained?

Knowledge, if it is to be a goal worth pursuing, must be conceived as a coordinated set of judgments about the real dynamics of the natural physical and social world, judgments that are thorough enough, accurate enough, close enough to being fully true, that we can act effectively to achieve the individual and social ends we value. Should our knowledge of human social dynamics and human valuings ever become thorough enough, and true enough, it is possible that that social knowledge might allow us to effectively critique our valuings, as well as our beliefs. If so, we may manage to choose our ends wisely, so that our pursuing and achieving of immediate goals does not lead us to destroy the more essential values we eventually come to see.

Reforming our human-to-human inter-relationships, and our human inter-relationships with rest of nature, requires action, and action requires knowledge, in the modern scientific sense. Conferring the title of "knowledge" on every belief system, as a way of according respect to persons, is not a step in the right direction. The consequence of such a move is that we develop societies that pay no special heed to the scientific knowledge so far achieved, not even when making momentous and perhaps irreversible decisions about social action.

The solution to, or the amelioration of, the urgent social problem of global warming depends on scientific knowledge of the problem, the conditions of occurrence of the problem, and consequences to be expected from our actions, given its occurrence. The problem of global warming is but one of the many potentially disastrous consequences of past and current human action in the real world, which will interact with us, responding to our actions, as it must, regardless of our expectations, our wishes, or our regrets.

The social structure that has emerged in the democracy of the U.S. has brought into positions of power the sort of persons who, for reasons of ideology, or religious belief, of personal greed, of hubris, or of sheer ignorance, refuse to make use of the best scientific knowledge of the day as a basis for political/economic/social action. Those who have the least, in every global village, can be expected to be those who suffer first the ill effects of unmitigated global warming. Given this, the development and employment of modern scientific knowledge is a matter of social justice.

It would go too far to lay the blame for the scientific somnambulence of the populace solely on the schools and on science education. It would go too far, too, to blame this solely on the current popularity of a thesis which holds that genuine knowledge of the world dynamics is impossible, and that it is therefore only fair to confer upon every belief system, however generated, however likely or unlikely to be true, the title of knowledge, or better yet, science. But, the misrepresentation of the nature of modern science, and its distinctive cognitive value, in the course of

science education, cannot have good consequences for the scientific literacy of a culture. It prepares the way for the acceptance of "alternative facts" and "alternative truths" in Donald Trump's presidential-advisory circles.

The cultural studies of science education theses appear to be motivated in large measure by misguided conceptions of social justice. The achievement of social justice is taken to require giving equal respect to all cultural systems of belief and methods of fixing belief. However, social reform, to be effective, requires a highly developed scientific knowledge, knowledge of the complex dynamic conditions that generate and maintain the pervasive systems of social injustice currently dominant across much of the world. Critical evaluation of the cognitive worth of conflicting systems of beliefs claimed to be knowledge is a necessary condition for the reform of the current situation of rampant social injustice.

Social justice should be conceived as a matter of actually achieving, in the real world, a just distribution of social goods and social opportunities, along with the freedom and ability to effectively pursue valued ends, through socially just means. In this sense, social justice is a critically important goal. But social justice is not achieved simply by asserting that equality exists, not even when that assertion is backed up by elaborate word magic. Re-conceiving scientific knowledge and scientific inquiry so as to be inclusive of any and all cultural belief systems, no matter how the system is achieved, no matter how inefficacious the supposed knowledge is, is not a means of actually achieving social justice.

Modern scientific knowledge is fundamentally different from other belief systems, in that the process of scientific inquiry provides a way of assessing the truth, in the sense of correspondence, of the beliefs about the world that science generates. A scientifically produced belief system is demonstrably more efficacious than other belief systems in facilitating successful interactions in the world, and progress toward the achievement of desired future states.

4.3 The Basics of Modern Science

A well-established body of scientific knowledge is a body of logically inter-related statements about the interactive dynamics of the natural world, which together constitute theoretical knowledge of the world. The theories, and the statements which comprise them, are understood to be true of the world, in the correspondence sense. The processes of interaction in the world, guided by theory, provide a continual testing of the truth of the scientific theory.

Well-established knowledge, understood in this sense, is a valuable outcome when achieved, and well worth the pursuing. It is the function of a body of knowledge to guide action in the world, in such a way as to solve problems set in and by the world, i.e., in the natural situations in which organic actions occur.

The process of scientific inquiry is the interactive process through which hypotheses, statements of possible interactivities, possible meanings of events, are generated, elaborated and tested by action in the world. The goal of scientific inquiry is to

pursue true beliefs about the world. The continual social process of scientific inquiry leads to the progressive development of knowledge of the world.

If modern science cannot reach knowledge of an existing and operative set of dynamic interactions, and the probabilities thereof, then there is no point to doing modern science. There is little advantage to be gained by achieving a cultural consensus in beliefs about the world, if those beliefs are not well-warranted to be true of the world, in the correspondence sense. The only advantage in arriving at and maintaining a fixed belief system which is not well-warranted to be true of nature is the fostering of a feeling of solidarity, of community of belief. But false beliefs about the world are likely to lead at some point to actions in the world that fail miserably in achieving the desired goal.

The statements that are well-warranted by experimental scientific inquiry to be true may, on further scientific inquiry, be shown to be false. But, as part of the ongoing process of scientific inquiry, the early judgments of truth, though later falsified, are valuable. They set the stage for further inquiry. The continual process of testing the results of prior scientific inquiry leads to the continual correction of errors, and improvement over time of knowledge of the world.

Even true beliefs can lead to failure in action, when combined with false subsidiary statements, or unrecognized complications in the situation. Nevertheless, a set of mostly true beliefs will generally be better as a guide to action than a set of mostly false beliefs. It should also be stressed that scientific inquiry provides no guarantee that the resulting judgment about the world is true. All that can be provided is a strong warrant to believe that the judgment is true.

The epistemic goal of having true beliefs (correspondence sense) about the world is justified by its contribution to achieving valued end states of action. But, this practical consideration of the usefulness of scientifically generated belief should not be mistaken for the criterion of truth. The criterion that permits the assertion that a judgment is true is the scientific inquiry process itself.

4.3.1 Scientific Inquiry, Correspondence Theory of Truth, and Knowledge

Mario Bunge sets out an account of the scientific method, in general, of the meaning of ‘scientific knowledge’, and of the correspondence conception of truth regarding the world (Bunge 1967/1998). The scientific method, in Bunge’s view, requires first, a problem situation, second, a more precise statement of the problem (p. 9), a set of hypotheses (guesses) as to the actual dynamic interactions constituting the problem, and a testing of the hypotheses, through deduction of some of the observable consequences of the hypotheses, and then action on the basis of the hypotheses, to test the agreement of the predicted results of the action with the actual results of the action.

Bunge’s account of the scientific method (see Bunge 2006) is remarkably similar to that of John Dewey. That the two descriptions *are* similar is remarkable, given the

prominence of long-standing misinterpretations of Dewey's philosophy, which take Dewey to have followed the subjectivism of William James, and/or the idealism of Hegel.[21]

The process of scientific inquiry leads to judgments about the interactions of the world. Judgments, as such, are always reached under conditions of uncertainty. What is desired, then, in addition to the judgment itself, is an assessment of the strength of the reasons to accept the judgment, tentatively, as true of the world. The process of inquiry itself provides such reasons. To the degree that the inquiry process is competent, the warrant for the truth of the judgment is strong. Assessing the quality of the inquiry process, clearly, is itself a matter of judgment. The ineluctability of human judging in inquiry is the reason that scientific conclusions must always be held tentatively, and are always in principle fallible. Dewey conceives knowledge as warranted assertibility, in this sense.

The lack of certainty in scientific inquiry does not affect the concept of truth. The pursuit of true belief about the dynamic interactions of the world, if truth is to be worth pursuing, requires a correspondence conception of truth. Vision presents the conception of truth as correspondence to the world in this way: "the truth of a proposition is constituted by a state of the world being such that were the proposition stated, it would state the world to be that way…" (Vision 2004, p. 87). On this view, a proposition is true if and only if the proposition refers to and accurately represents certain of the dynamic interrelationships of nature. This definition may seem to have a built-in circularity that makes it tautologically true, in so far as the term 'accurately' has the same meaning as 'truthfully'. But this is characteristic of definitional, analytic, statements. (Every dog is a member of the genus Canidae; the genus Canidae is the genus including all dogs.) What is required is more than a definition; what is required is a fuller account of the meaning of the concept of truth, and an operational definition, i.e., an account of what activities should be undertaken if a statement is to be rationally considered to be true.

The correspondence conception of truth is controversial, and often rejected. In *Nonsense on Stilts*, Pigliucci develops a strong indictment of pseudoscience and non-science masquerading as modern science. Yet, Pigiucci rejects the correspondence conception of truth, and links the correspondence conception to "scientism", by which Pigliucci means the intrusion of scientific inquiry into non-scientific questions. "[T]he entire scientistic attitude rests on a specific philosophical theory known as the 'correspondence theory of truth'"(Pigliucci 2010, p. 236). Pigliucci states that "the correspondence theory of truth essentially assumes that somehow we can step outside of what philosophers call our 'epistemic limitations'…and access a 'God's eye view' of things" (p. 237). However, Pigliucci accepts that it *is* possible to "show that the claims scientists make about science are in fact correct" (p. 264). But, what does the term 'correct' mean here, if not "true", in the correspondence sense of truth?

Truth, in the correspondence sense, is an absolute—a proposition is either true or false, and the world is the truth-maker. To attain "the truth, the whole truth, and

[21] See McCarthy 1996a, b, 2000, 2002, 2007a, b, and McCarthy and Sears 2000.

nothing but the truth", would be nice, but unfortunately is impossible. This is in part due to practical human limitations of time and effort, but, more importantly, it is impossible because attaining the "whole truth" about nature would require knowing every possible interactive event in nature. And this is logically impossible, because the set of all possible interactions is infinite, since every concatenation of actual or possible interactions, past, present and future, must be accurately represented.

The key to resolving this conundrum is to conceive of an all-true belief-system as a goal of inquiry. As a goal, it is an ideal, in the sense that it is a desirable and desired future state of affairs, not currently present, toward which we choose to work. If it were not humanly possible to even assess our progress toward that goal, the goal should be revised and/or rejected. The relevant question then is: Is there a way that a human being can assess the correspondence truth of a proposition, or of a theory? The answer to this question, I will argue, is "Yes."

But, how? In what sense? By what method? The Deweyan conception of experimental inquiry sets out a means to pursue the goal of a belief system that is increasingly true in the correspondence sense of the term 'true'. Dewey raises, and responds to, the question: "What is the experience in which the survey of both idea and existence is made and their agreement recognized?" (Dewey 1907, p. 79). Dewey presents the standard conundrum: in any experience, either both idea and fact are present, or only one, the idea *or* the fact, is present in experience. If 1: both fact and idea are present, no comparison of the two is necessary, for the facts are there in *propria persona*. If 2: only ideas are present, there can be no comparison, by definition. And if 3: only facts are present in experience, a comparison of idea and fact to check their agreement, their correspondence, is both impossible and unnecessary. This analysis would seem to be sufficient grounds for rejecting the correspondence conception of truth.

Dewey offers a solution to the apparently inescapable dilemma. But, it is a hard one to accept. The solution is that one must reject, completely, the metaphysical position of dualism. Dualism is the notion that there is one sort of thing called an "idea", which belongs to a "mental" realm, and another sort of thing, called a "fact," which belongs to a material realm. It is the assumption of dualism that leaves the correspondence conception of truth seeming untenable.

Dewey argues that having an idea is an existing occurrent thing/event, an interactive happening between a *human* thing/event and other, *non-human*, thing/events, in a situation. Both the idea and the fact of the matter are equally present in a situation of scientific inquiry, and thus can readily be compared. But, why would one do so? Why even form ideas, if, when one is fully immersed in the factual situation, the agreement or disagreement of idea and world is obvious?

One forms ideas because one's present situation is problematic. A necessary condition of a situation being "problematic" is that a person in the situation has a goal, an end-in-view, a future state of affairs that is desired, but that is not actually present, not currently existent. Action must be taken to bring about the desired future state (unless one chooses to wait for the chance occurrence of the desired state, or to hope for the action of others). If, given the person's history, and thus the person's present (physical) cognitive state, the course of action needed is clear, then no

thinking process is needed; one simply acts on one's knowledge. What makes a situation problematic is that, in it, the person's current knowledge has proven to be inadequate. The person sees no clear connection between: the present situation; his or her action; and the occurrence of the desired situation. The person cannot effectively act, and so must stop, and think.

In such a situation, i.e., a situation requiring the activity of thinking to guide one's future action, the conception of correspondence truth makes sense. One has a present engagement with the problematic situation, open to inspection. One develops an idea, which is a potentially useful plan of action. An idea is an organismic state, a representation, which has two parts: (a) what is thought to be the nature of the problematic situation; and, (b) what is thought to be the active interventions that will change the existing situation, over time, into the desired situation.

Over the period of time while one acts guided by the idea, one is, clearly, fully present, physically/cognitively, in the developing situation. And one is fully present in the situation *that results* from one's acting. The idea one has formed can thus be tested through one's action. The idea leads one to expect a new situation of a particular sort to occur as an effect of certain actions taken under certain conditions.

Following action, one is in a position to compare (a) one's idea of the dynamic interactive relations constituting the problem situation to (b) the results achieved through the actions that are based on that idea. The result expected is compared to the result that occurs. If the two are different, there is something wrong, and the inquiry should continue.

For example, suppose one is lost in the woods, and desires not to be lost. One examines the current situation in light of one's existing knowledge, and develops an idea, a course of action thought likely to resolve the problem, to get one out of the woods. One acts, to test the truth of the idea, and discovers through action whether or not one's idea was adequate to solve the problem. If one succeeds, there is reason to think that one's idea of the environment, of one's position in it, and of the actions that will take one from the present situation to the desired situation, was true, in the correspondence sense. It is possible that the idea was false, and one just experienced epistemic luck. Because epistemic luck is always a possibility, genuine scientific inquiry must be a continual process, undertaken by an extensive community of inquirers. Given this, the epistemic luck, if a factor, is likely to be eventually discovered.

This is the basic structure of scientific inquiry. One faces a problem, a puzzle of some sort. In light of one's knowledge (best current theories), one forms an idea, a hypothesis, i.e., "If the dynamic relations constituting the situation *are* as I now *think* them to be, then, if certain actions are taken, the resulting situation *will be* the one I predict will occur". One acts on the hypothesis, and discovers whether or not the hypothesis (the idea about the consequences of particular actions in the particular situation) agrees with, i.e., corresponds to, the actually observed consequences that result from action in the problem situation. New evidence is thereby generated about the agreement or disagreement of idea and world. As a result of experimental reflection and action, an advance toward the epistemic goal of true belief has been made, and new knowledge has been acquired.

The *dis*agreement of the hypothesis, in some respects, with the situation in question, is the usual result. This result leads to a re-thinking of the nature of the actual dynamic interactions of the situation. A new or revised hypothesis (idea) is formulated, and one acts to test the new hypothesis. The process of experimental inquiry is repeated again and again by a large community of inquirers who are acting, as a practical necessity, in a social and cultural framework that supports the scientific inquiry process. Over time, a body of established scientific knowledge is developed.

It is the ongoing process of scientific inquiry that stands as the warrant, the justification, of the claim that the belief-system built up over time counts as genuine knowledge. For the sake of clarity, Dewey uses the new term 'warranted assertion' in place of the customary but ambiguous term 'knowledge'. A "warranted" assertion is an assertion that is supported by strong reasons, provided by the results of continual scientific inquiry, to accept the assertion as true, in the correspondence sense of truth set out by Dewey.

Dewey makes it clear that this correspondence sense of the meaning of the term 'true' is the one that he employs in his theory of knowledge, which he calls "instrumentalism".[22] Dewey writes: "Instrumentalists …do *not* believe the test of truth is coherence; in the operational sense …they hold a correspondence view." (1941, p. 172, fn. 7).

A correspondence conception of truth makes sense when correspondence is understood in the operational sense describe above. The operations of experimental scientific activity make it possible to assess the correspondence truth of a hypothesis by means of experimental evidence, and to build a strong warrant for belief that the dynamics of the occurrent situation are as they are stated to be. The well-warranted assertions that result are knowledge. Scientific inquiry is an ongoing, organized social activity, with a large community of scientists engaged in experimental activity to test the truth of various ideas about the world, and to test and improve the experimental means of testing ideas. The result of scientific inquiry is a set of well-warranted judgments about the correspondence of ideas to the dynamic interactions of the world. Scientific inquiry in this sense is a necessary condition for development of a high-quality body of knowledge, understood as a set of statements strongly warranted to be true of the world.

The term 'knowledge' is ambiguous, as it is used to refer to at least three fundamentally different things. Disambiguation is needed. To refer to well-warranted beliefs about the world developed through scientific inquiry, the term 'modern scientific knowledge' seems *a propos*. To refer to a set of beliefs that has arisen from everyday concourse with the world, though without the benefit of scientific inquiry, it seems that the term 'common-sense beliefs' would serve well. To refer to a set of beliefs not tested by modern scientific inquiry, that are longstanding culturally

[22] The term 'instrumentalism' in Dewey's philosophy refers to the instrumental use of propositions in scientific inquiry, as essential tools of the inquiry process. Dewey's choice of term was unfortunate, as the term 'instrumentalism' has come to denote an epistemological anti-realism, a view that is inconsistent with Dewey's epistemological position, and with modern science.

accepted beliefs about the world, what term should be used? The term 'culturally established belief-system' would seem to be appropriate.

This terminology would be controversial, for the term 'knowledge' has a strong normative connotation. Whatever beliefs are taken to count as knowledge about the dynamic inter-relations in the world are generally understood to be beliefs that are true. Dewey puts it this way: "My analysis of 'warranted assertibility' is offered as a *definition* of the nature of knowledge in the honorific sense according to which only *true* beliefs are knowledge" (Dewey, lw.14.169).

Hence, to use the term 'knowledge' only in connection with scientifically warranted beliefs will be unpopular in some quarters—whatever the source of belief, and to whatever extent the truth of that belief has been tested, it seems that most persons wish their belief-set, however obtained, to be referred to as their "knowledge". But, epistemologically, the distinction between knowledge and belief is fundamental, and should be distinctly marked terminologically. (The term 'scientific knowledge' is thus redundant, but makes up for that by being very clear.)

It may be that the term 'knowledge' has accumulated too many conceptualizations disparate to the meanings implicit in modern scientific knowledge to be useful. It was this consideration that moved Dewey to introduce the term 'warranted assertion' to refer to a modern scientific statement of knowledge, and 'warranted assertibility' to refer to knowledge in the abstract.

4.3.2 Reality and the Objects of Modern Science

Baggott (2013) sets out an informative account of quantum theory in modern physics. Baggott adopts six principles that he asserts are the "Authorized Version" of the fundamental concepts related to modern science. Several of these theses, however, are problematic. Baggott's "Reality Principle" follows a Kantian track: he accepts that "Reality consists of things-in-themselves of which we can never hope to gain knowledge" (Baggott 2013, p.8). We must then, Baggott accepts, "content ourselves with knowledge of empirical reality, of things-as-they-appear or things-as-they-are-measured" (Baggott 2013, p.8). Given the belief that "reality" is inaccessible, Baggott believes that scientific realists can only "assume" that "reality (and its entities) exists objectively and independently of perception or measurement" (Baggott 2013, p. 8). But, having to merely assume this fundamental claim is an unacceptably weak position. The conceptualization of reality given by Baggott needs revision.

Baggott's "Fact Principle" is similarly flawed, leaving modern science inadequately conceived. The statement of this principle begins well: "Our knowledge and understanding of empirical reality are founded on verified scientific facts derived from careful observation and experiment"(Baggott 2013, p. 12). Baggot then adds: "But the facts themselves are not theory-neutral. Observation and experiment are simply not possible without reference to a supporting theory of some kind" (Baggott 2013, p.12).

This principle founders on an ambiguity inherent in the term ‘facts’. The term ‘the facts’ can be used to refer to the actual interactive relations that constitute the world—the dynamic relations of thing/events. The facts, in this sense, will be just what they are, regardless of human beliefs about them, and independent of theories about them. It is only when humans interact with the facts that human beings can bring about changes in a factual situation.

In a different sense, the term ‘the facts’ can be used to refer to the theoretical interpretations of the interactions of the world, as they are believed to be. In this sense, it is trivially true that “the facts”—the well-tested and well-warranted assertions—are related to the theories one accepts. Because of this ambiguity, it seems advisable to refer to “what is” using the terms ‘nature’, or ‘the world’, or the set of ‘dynamic interactive events’ currently of interest.

Experimental research projects are guided by *tentative* theories, and are designed to test the theory in question. One can truly say that experimental work is, by definition, and *should* be, theory-guided. But, the interactive dynamic relations that constitute reality will occur regardless of the desire of the scientist to see his or her guiding theory confirmed. The results of the testing are independent of the theory being tested, which is to say that the actual interactions undergone are not theory dependent. Expected results are, by definition, theory-dependent, but actual results are not.

4.3.3 Reality, as “What Is”, and Truth

An entrée to the ontological question of reality may be made by considering the nature of human beings, and our experience, or, more broadly viewed, the nature of living organisms and our experiences. Living organisms, at a basic level of analysis, are simply certain sorts of happenings, that is, they are things/events which share certain kinds of dynamic interactions with their environment that warrant the classification as “living”. Living organisms are simply a subset of the dynamic interactive things/events that, in their entirety, constitute nature, or reality, or “what is”.
The *experience* of a living organism is not in any way separate, or separable, from the rest of nature, from the dynamic interactions that are natural things/events. The term ‘environment’ refers to the subset of the surrounding natural thing/events with which the organism is, at a particular time, in interaction with. The environment includes other organisms, as well as every other sort of interactions For example, a human creature is normally in interaction with “breathable air”, this being air having the concentration of oxygen and carbon dioxide (along with a vast number of other molecules) that is consistent with the continuing life of the creature. But, the environment can change, and that change can be caused by interactive events that seem far removed from the creature. The organism’s environing conditions thus actually extend far beyond the location of the organism.

This view is ontologically naturalistic, in the sense that there is held to be no such thing as a separate other-than-natural sort of Being. On this view, the interactions commonly termed 'mental' are simply a designated subset of natural organismic interactions. The term 'mind' refers to a certain subset of interactions internal to the creature that contribute to determining the activities of the creature. Mind, in this sense, includes cognitive, affective and volitional dynamic interactivities internal to the creature, that tend to guide its action in the environment.

Every organism is in continual interaction with its environing conditions. When the organism is complex enough to respond to certain interactions as signs, taking certain things/events to have significance for action, then the organism has the beginnings of mind. If the significance, *the meaning*, of the interactive experience is retained in the organism, so that past experiences can become operational factors in guiding future actions, then the organism has a full-fledged mind. Mind, in this interpretation, is simply a system of organismically conserved beliefs and dispositions. When intentional social communication of meanings comes into being as an elaborate form of interaction, a language evolves, and a culture begins to develop. When the communicative organisms in a cultural setting are of sufficient social complexity, then, the system of meanings that is mind can be given an extra-organismic place in the world, e.g., in books.

This understanding of organisms, of experience, and of mind, is central to Dewey's naturalistic realism. The "mental" is simply one subset of the dynamic interactions that contribute to determining the actions of the organism.

This view is also ontologically realist, in the sense that the interactions that constitute nature are for the most part not dependent upon the beliefs, wishes or desires of living organisms. The exception is obvious: this "independence of nature from organismic belief" obtains, *except* when the organism itself is one of the causal factors in interaction. As an organism acts, it will, being a natural concatenation of interactive events, participate in the determination of the interactive events that constitute the emerging situation.

But, if an organism fails to (more-or-less) accurately represent the current state of dynamic affairs, the organism will be less able to act in pursuit of its goals, e.g., maintaining its living state. So, for example, in the event of a tornado, the organism's taking shelter will affect the developing situation. But, the organism's *belief that* it is safely sheltered does not mean that it *is* safely sheltered. A belief about the world, by itself, does not affect the dynamic interactions of the world. It is in this particular sense that reality is independent of belief.

Beliefs are only useful to the organism when they do shape the organism's action. The organism's beliefs, and its linguistic statements of belief, if applicable, are only likely to successfully guide action if they are true in the correspondence sense of truth. Modern science is the highly elaborated and rigorously tested process of the testing of tentative, potential beliefs. The goal is to develop knowledge, a set of beliefs about the interactive events of the world, and the conditions and consequences of their occurrence that is well warranted to be true to the world.

4.4 Conclusion

In *Experience and Nature* Dewey wrote, "To entertain and believe fancies which once were spontaneous and general is today a sign of failure, of mental dis-equilibration. Inability to employ the methods of forming and checking beliefs which are available at a given time, whatever be the source of that inability, constitutes a disorientation" (Dewey 1925, lw.1.175).

Respect for persons does not entail respect for the belief-systems of those persons. Respect for persons entails respect for the capacity of those persons to engage in the fundamentally human activities, among which is capacity to search for true belief. Respect for persons thus entails commitment to the support of each person in their quest for true belief. Respect for persons entails, among other things, a commitment to the equal distribution of the social good of education. It means respectful, and mutual, critiques of one another's belief-systems, leading to mutual thought and the self-critique that is essential to the individual's growth in cognition and in all other capacities.

To fail to teach to one's students the critical evaluation of their own current belief-systems, which is necessary in the effort to maximize true belief and to reduce false belief, is a matter of fundamental disrespect for persons, and constitutes a profound mis-education. No culture is free from error, and none is immune to an overgrowth of destructive superstition. Growth in scientific knowledge – a genuine, modern, and growing scientific knowledge – is a necessary condition of effective human action to counter the destructive effects of human action on the global environment, and hence, increasingly, on ourselves.

The state of cultural antagonism, of personal disrespect, and all too often, of hatred for the "other", the different, is one of humanity's chief problems. But, the thesis promoted in cultural studies of science education literature, that respect for others requires according equal respect to non-scientific methods of inquiry and to systems of belief about the world not warranted by scientific inquiry, is a recipe for social injustice. The essential goal of science education should be to advance social understanding of the methods of science and scientific knowledge about the dynamics of the world. This is of critical importance if we are to effectively respond to the urgent issues we currently face.

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