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Contextual Constructivism: The Impact of Culture on the Learning and Teaching of Science

Though rooted in Piagetian research, constructivism[1] is an avenue of research pertaining to teaching and learning that departed from the neo-Piagetian[2] mainstream twenty years ago and has continued on a distinct path of development. The departure was evident by the late seventies, clearly marked by two publications, Novak (1977) and Driver & Easley (1978). For constructivists, learning is not knowledge written on, or transplanted to, a person's mind as if the mind were a blank slate waiting to be written on or an empty gallery waiting to be filled. Constructivists use the metaphor of construction because it aptly summarizes the epistemological view that knowledge is built by individuals. Since Ausubel, Novak, & Henesian (1978), theorists have argued that the construction of new knowledge in science is strongly influenced by prior knowledge, that is, conceptions gained prior to the point of new learning. Learning by construction thus implies a change in prior knowledge, where change can mean replacement, addition, or modification of extant knowledge. Learning by construction involving change is the basis of the Posner, Hewson, & Gertzog (1982) conceptual change model. In essence, constructivism is an epistemological model of learning, and constructivist teaching is mediation. A constructivist teacher works at the interface between curriculum and student to bring the two together in a way that is meaningful for the learner.

If one carries the construction metaphor to its logical conclusion, construction implies a foundation in addition to the studs and beams of prior knowledge. The construction of new knowledge takes place at a construction site consisting of existing structures standing on a foundation.[3] In other words, construction takes place in a context - a cultural context created by, for example, social and economic class, religion, geographical location, ethnicity, and language. This chapter begins by setting the concept of contextual constructivism within the historical development of constructivist theory and then examining the types of questions suggested by contextual constructivism. Those questions are then placed in the context of an anthropological world view theory. The chapter concludes with a discussion on the necessity of qualitative research techniques for contextual constructivist research.

The Evolution of Constructivism

Piagetian theory has dominated educational research in the second half of the 20th century, and continues to do so. In science education the publications of A. E. Lawson provide some of the best examples of neo-Piagetian research, that is, Piagetian-based research with a nomothetic focus on mental stage theory.[4] In the 1970s, however, a derivative of Piagetian research emerged (see Figure 1). Researchers in what is

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Insert Figure 1 about here.
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now called the constructivist movement maintained Piaget's structural philosophical position, but opposed continuing a research focus on the application of cognitive-stage theory common among the neo-Piagetians of that time period. Instead, they argued for a new epistemological focus on the actual content of student thinking, that is, a focus grounded in Piaget's ideographic work. In science education the emergence of the constructivist movement as a formidable avenue of research was clearly signalled by two seminal publications, Novak (1977) and Driver & Easley (1978).[5] In the 1980s, the philosophical work of von Glasersfeld (1989) on radical constructivism served to correct the movement's drift towards empiricist epistemology (Staver, 1986).

At the heart of constructivism is a particular view of knowledge. Knowledge held by an individual is assumed "to have a complex set of referents and meanings" (Magoon, 1977, p. 652) which must be taken into account when a researcher is trying to understand how learning takes place. It is this complex of referents and meanings that led researchers to draw upon David Ausubel's (1963) theory of meaningful learning with its "emphasis on the preexisting conceptual structures to which the students had to relate new items of knowledge" (Solomon, 1987, p. 64). In addition, constructivism involves a distinctive view of the student. From the constructivist perspective students are knowing beings who construct knowledge that is personally meaningful. In fact, in an earlier chapter von Glasersfeld refers to constructivism as a theory of knowing, rather than a theory of knowledge. Thus, to understand learning the researcher must come to an understanding of the construction process of knowing. The focus is on the student as constructor (Magoon, 1977). Early on constructivism emphasized the individual, and thus, the initial constructivist departure from Piagetian research is best termed personal constructivism.

The emergence of personal constructivism in science education had important consequences for science education research. Personal constructivism precipitated very different types of research questions, pertaining not to nomothetically viewed mental stages, but to the actual content of student conceptions. It is interesting to note that neo-Piagetians such as Lawson maintained a focus on mental stages but replaced Piaget's interview methodology with paper-and-pencil instrument methodology. Constructivists took the opposite route. While moving away from a focus on mental stages, they kept and further developed interview methodologies. Highly structured Piagetian interviews gave way to the less structured interview-about-instances format (West & Pines, 1985) and phenomenographic techniques (Marton, 1988), becoming increasingly qualitative.

Student Conception Research

As noted constructivist research meant a switch in focus from mental stages to the actual content of student thinking. This was in part due to a perceived lack of progress in neo-Piagetian research with respect to improving the efficacy of classroom instruction. Of equal importance, however, was the influence of epistemological studies in the philosophy and history of science. Kuhn's seminal work on scientific revolutions resulted in a lively, enduring debate concerning the development and nature of scientific knowledge (e.g., Shapin, 1982). In the 1960s and 1970s with eye on these events, science educators around the globe conducted numerous nature of science (NOS) studies. This conceptual research was conducted to elucidate how well student and teacher conceptions of what science is about fit with the researchers' philosophical models. NOS studies ran their course, but research interest in student conceptions continued. Constructivists turned to questions of greater specificity. Rather than asking what students believe science to be about, they asked, what is a student's construction of (say) gravity and how does that construction compare with the authorized version (i.e., epistemological truth) of science? The research focus was the student's experience in the natural world and his or her attempts to make sense of experience vis-a-vis concepts of science. The research quite naturally emphasized specific concepts of interest in science education, for example, motion, force, natural selection. Knowledge that compared poorly was called a misconception (MC) or alternative conception (AC).

Conceptual research is important to constructivists because learning is often viewed not merely as a process of assimilation and accommodation, but as a process of deconstructing misconceptions and reconstructing valid scientific conceptions in their place. At first the construction process was considered a personal experience and essentially rational:

> Our central commitment...is that learning is a rational activity. That is, learning is fundamentally coming to comprehend and accept ideas because they are seen as intelligible and rational. Learning is thus a kind of inquiry (Posner et al., 1982, p. 212).

In the personal constructivist view, conceptual change occurs when a student personally finds that science conceptions are more intelligible, plausible, and fruitful than his or her own priorly held conceptions. Driver (1983) and Driver, Guesne, & Tiberghien (1985) are classic presentations of student conception research. The burst of enthusiasm for student conception research, nurtured by studies in epistemology and stimulated by the fascinating research of Driver among others, was attested to when Cornell University convened international conferences solely for the purpose of presenting MC and AC research (Helm & Novak, 1983; Novak, 1987). Personal constructivism continues to be a productive avenue of research as demonstrated by the large number of conceptual change and MC papers read at the 1991 annual meeting of the National Association for Research in Science Teaching (NARST, 1991).

Nevertheless, the overall result of applying MC and AC based conceptual change ideas has been mixed (Gunstone, White, & Fensham, 1988; Rowell, Dawson, & Lyndon, 1990). It has not been found that students easily give up their prior ideas. Critics of the conceptual change model consider it excessively rationalistic: "We want to argue that nonrational components are intrinsic to conceptual change in the individual, and that these should not be excluded in investigations of conceptual change" (West & Pines, 1983, p. 37). West & Pines listed power, simplicity in complexity, aesthetics, and personal integrity as potentially significant nonrational components of conceptual change. As early as 1982, Novak raised the Vygotskian point that environment can influence the conceptions children have about natural events. Sensitive to the critics and perhaps concerned by an apparent lack of sufficient progress in conceptual change research, Strike & Posner (in press) recently revised the conceptual change model. They agreed that the original model was indeed excessively rational and in need of broadening. Referring to Toulmin's (1972) notion of conceptual ecology, Strike & Posner (in press) note that the conceptual change theory "can be stated in a more general form by emphasizing that what it centrally requires is a focus on the learner's conceptual ecology and how that ecology structures learning."

Joan Solomon's work is an excellent example of the more ecological approach to student conceptual research. Solomon exploited sociological perspectives to help her understand the anomalies found in student conceptual research. Drawing from Mead (1934) and Berger & Luckmann (1967), Solomon (1987, p. 66) argued that student ideas about nature stem "not from the logical processes of which science boasts, but from the 'common sense' attitude that relies on being able to interchange perspectives and meanings with others." The notion of "interchange" introduces a social element. Thus, Solomon made social interactions in the science classroom the focus of her research on student learning. "As students interact with one another, with teachers ... they develop ideas that, because they are held in common, create a universe of discourse, a common frame of reference in which communication can take place" (quoted in Solomon, 1987, p. 68). The identification of commonsense and social interaction as factors in learning brings one to the crux of how Solomon's research differs from personal constructivism. Solomon cogently argued that a crucial component in learning is context, and in particular that learning takes place the context of social interaction. Context, however, can be more broadly defined. Millar's (1989) edited volume, for example, contains a series of articles by science education researchers who share the view that research on teaching and learning must be contextualized not only socially, but epistemologically and culturally as well.

To briefly recapitulate this historical sketch, the initial break with Piagetian and neo-Piagetian research involved refocusing research on students' actual ideas about nature, i.e., an ideographic rather than a nomothetic focus. This became the basis for a rationalistic, personal constructivist notion of learning. However, a perception of insufficient progress toward improved science instruction led some researchers to doubt the theoretical adequacy of personal constructivism. Drawing on sources in the sociology of knowledge, Solomon (1987), Sutton (1989), and Millar (1989) among others, have moved the science education research field from personal towards contextual constructivism. Thus far two metaphors, the construction site and cognitive ecology, have been used to convey the meaning of contextual constructivism. The metaphor of ecology draws one's attention to the interactiveness of context and environment, and is adequately understood in terms of Piagetian assimilation and accommodation. Construction site conveys the notion of foundation and stability, and is the metaphor more central to the purpose of this chapter.

Culture as Context

What has not significantly changed in the move from neo-Piagetian theory to personal constructivism, to a nascent contextual constructivism is the logical empiricist assumption that student views or ideas must ultimately be measured against science conceptions. While not wishing to elevate all student ideas to the level of sacrosanctity, cultural studies indicate that students have other grounds for evaluating ideas. Student views "provide a different sectioning of experience precisely because the pursuit of scientific knowledge is not the only or even the most important goal they subserve" (Hills & McAndrews 1987, p. 216). Student views are grounded in cultural milieu, and as the renown anthropologist Clifford Geertz wrote, "man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs, and the analysis of it is not an experimental science in search of law but an interpretive one in search of meaning..." (Geertz, 1973, p. 5).

Broadly defined, culture is a system of meaning and significance, with the term "system" used advisedly.

> Even the assumption that culture is relatively coherent is under debate. Contemporary critical theory has now posed a major alternative view: culture as multiple discourses that may occasionally come together in large systemic configurations, but that more often exist together within dynamic fields of interaction and conflict (Outram, 1990, pp. 327-328).

Thus, one must not suppose that cultural identification is limited to such conspicuous group identifiers as race, language, or ethnicity (e.g., Schatzman & Strauss, 1966). Black America, white America, Spanish speaking America, English speaking America, each of these no more identifies a homogeneous cultural group than does the term American. While there are elements of culture broadly shared in the United States, so that one is justified in speaking of (say) American culture, the United States is composed of many cultural subgroups most of which are subgroups embedded within other subgroups (see Figure 2).

Insert Figure 2 about here.

In addition to race and language, other significant factors influence the construction of meaning and therefore are part of cultural identity. These include economic and education levels, occupation, geographic location, gender, religion, and philosophy. Thus, one can expect to find considerable cultural variation among students. A student constructs knowledge so that the knowledge is meaningful in the student's life situation. Although it can be profitable, it is not sufficient to investigate student views as strictly personalistic views, nor to unilaterally investigate student views vis-a-vis authorized science conceptions. Contextual constructivism carried to its logical conclusion compels the investigation of student views <u>within</u> the cultural context which gives meaning to those views. In the colorful phrasing of Hills (1989), this means a change from the study of "domestic affairs" in science education to the study of "foreign affairs."

Foreign affairs in science education is a more familiar idea for educators in non-Western nations where the difference between students' traditional culture and the culture of Western science is more visible. Non-Western educators, for example, understand that science is a second culture for students (Ogawa, 1989; Ogunniyi, 1988). Ogawa believes that,

> science, the product of western modernization, should be taught in the context of a foreign culture in school science in a nonwestern society. On the basis of this position, science teachers need not only to know the western science itself but also to be aware of the traditional and scientific ways of thinking, and views of nature (1989, p. 47).

In the past, American educators tended to assume that scientific explanation is a natural part of American student culture. But educators face two crucial facts. First, American society is increasingly pluralistic. Second, not only is there widespread disinterest in science among students, several cultural subgroups are significantly underrepresented in science, e.g., women, African-Americans, Hispanics, Native Americans (Vetter & Babco, 1987). There is ample reason to suspect that, as in some non-Western societies, science is indeed a second culture experience for many American students.

Traditionally, the study of culture is left to the cultural anthropologists. However, in recent years scientists, historians, and literary critics, among others, have undertaken cultural studies. What unifies these eclectic cultural scholars is that they "take a subject whose working assumptions are considered natural and attempt to demonstrate that they are culture-bound" (Heller, 1990). Cultural studies in science education have turned implicit assumptions into explicit research questions:

1. What do students and teachers believe about the world around them, especially the physical world?
2. How do students and teachers understand their own place in the world, especially their relationship to the physical world?
3. What is the cultural milieu in which these student and teacher beliefs, values, and relationships are grounded and supported?
4. What is the culture of science and how is that culture interpreted in the school science classroom?
5. What happens when student cultures, teacher culture, and the culture of science meet face to face in the classroom?

In other words, it is important for science educators to understand the fundamental, culturally based beliefs about the world that students bring to class, and how these beliefs are supported by students' cultures; because, science education is successful only to the extent that science can find a niche in the cognitive <u>and</u> socio-cultural milieu of students. Thus, the contextual constructivist researcher in science education is led to principal questions of cultural anthropology: <u>What does a people believe about the world and why?</u> The <u>why</u> is crucial, for this indicates the question is about culture. In cultural anthropology, these are the questions of world view.

The World as Others See It

We live in a rich experiential world brought to us by our senses, but the data of our senses is an amorphous mass of confusion until interpreted by one's world view. Sociologist Peter Berger (1979) argued that a people's world view provides a special <u>plausibility structure</u> of ideas, activities and values which allows one to gauge the plausibility of any assertion. This shared world view is a fundamental aspect of any cultural group. It may be argued that there is a cultural identity in Western science education, and that teachers typically assume students operate within that plausibility structure.

The original notion of a <u>heretic</u> was someone who decided things for himself or herself instead of employing society's plausibility structure or world view. In a sense, science classrooms are filled with <u>heretics</u> operating within other plausibility structures. Science educators recognize them by their alleged <u>misconceptions</u>. However:

> Talk of misconceptions...carries with it the suggestion that something has been botched or bungled, or that something has gone amiss...And there is often the further implication that the student is the culprit: that he or she is the one who has gotten something wrong... There is more to error than meets the eye (Hills, 1989, p. 174).

Indeed, there is more than meets the eye. As one begins to study world view, one finds that young children in the classroom are in the process of developing their own world views and plausibility structures. The school neither provides the sole nor principal influence upon this formative process. Older children, on the other hand, may come to class with highly developed world views. As a result, these students enter the classroom with culturally validated ideas about the world. But again, the school was not likely the principal formative agent, and thus the students' views are pejoratively labeled <u>misconceptions</u>. Whether with young children or older ones, educators face a difficult instructional problem.

World View Theory

World view, a concept borrowed from cultural anthropology, refers to the culturally-dependent, generally subconscious, fundamental organization of the mind. This conceptual organization manifests itself as a set of presuppositions which predispose one to feel, think, and act in predictable patterns. Kearney (1984, p. 1) referred to world view as "...culturally organized macrothought: those dynamically inter-related basic assumptions of a people that determine much of their behavior and decision making, as well as organizing much of their body of symbolic creations...and ethnophilosophy in general." Thus, world view is about the epistemological levels antecedent to the specific views that students hold about physical phenomena, whether one calls those views commonsense, alternative conceptions, misconceptions, or valid science. Adapted to science education, world view theory argues first that educators must try to understand the world as students understand it. If the goal in science education is successful science instruction for all, science educators cannot continue to deny legitimate variations among people. Only as science educators come to a better understanding of how people view the world and why they hold those views, can the structure of science education be changed so that science becomes meaningful for a broader range of people. The issue of science education structure, however, raises a second aspect of world view research: the close examination of the plausibility structures in science classrooms vis-a-vis structures actually necessary for science education. Ausubel (1966), Kilbourn (1984), Rigden & Tobias (1991), and Sutton (1989) all found presuppositions embedded in science curricula that are not only unnecessary in science, but also quite sure to conflict with the world views of many students. For example, Ausubel said of BSCS texts:

> The mechanistic bias in the... [yellow and blue] versions is excessively and unabashedly polemical... Although it is legitimate to express this type of reductionistic bias in the philosophy of science, it should at least be stated as a bias... (1966, p. 183).

Similar criticisms are frequently made in the feminist literature (e.g., Whatley, 1989).

As noted earlier, conceptual change theory argues that students learn science when they see that the scientific explanation is superior to the untutored, commonsense beliefs brought by them to the classroom. However, that only works when students share the plausibility structure of the science teacher and the science textbook. The documented difficulty in bringing about conceptual change plus the socio-cultural diversity of most classrooms is evidence that many students do not share this plausibility structure. Consider Hawkins' observation:

> The textbook says that heat flows from hot to cold, or that light travels in straight lines, or that the earth goes about the sun; the teacher tries to elucidate... But failure is often imminent. In each case, the intended communication is blocked, more often than not, by a radical mismatch between the presuppositions of the book or the teacher and those of the child. What the book and the teacher obedient to it try to communicate often presupposes (but fails to induce) a radical reorganization, in each case, of some commonsense category of experience. If our early grasp of motion is itself all <u>geo</u>graphical, then the earth itself surely does not <u>go</u> (1983, p. 75).

The mismatch indicates that for many students science is a <u>second</u> culture, in much the same way as American educators speak of English as a second language for some students. There is a disjunction between the world view (or views) of students and the world view of the classroom teacher and instructional materials.

The world view of students (and of classrooms), thus, has every appearance of an attractive avenue of research. Unfortunately, investigators have been hampered by a lack of theoretical clarity. For the most part, people who use the term world view do not define it, or define it only vaguely as one's view of the world, our understanding of man and nature, our type of thinking, how we understand cause and effect. The philosopher, W. T. Jones (1972, p. 79) listed thirteen different synonyms for world view, commenting that, "critics suspect that a concept so variously named is itself somewhat vague, and this suspicion doubtless explains why some students of culture prefer to ignore the notion of world view altogether." The vagueness of these terms is such that one has done little more than name a hypothetical entity. This ambiguity of definition results in many researchers failing to see how world view can be a useful concept in science education research. As a remedy, Cobern (1991a) has recently adapted for use in science education research a structuralist theory from cultural anthropology, logico-structuralism. After an extensive review of ethnographies, anthropologist Michael Kearney (1984) identified seven universally-found, epistemological categories. Logico-structuralism is the composite of those categories: Self, NonSelf, Classification, Relationship, Causality, Time and Space. Each category is composed of logically related presuppositions. The power of logico-structuralism lies in this composite structure. The seven categories alert the researcher to the complexity of world view while simultaneously providing access to that complexity. Yet, one can still characterize world views by focusing on what are considered to be the salient presuppositions within the seven universal categories.

To recapitulate, world view research focuses on foundational categories antecedent to knowledge as it has been typically investigated by MC and AC researchers. This type of research involves a broad, minimally restricted focus on general beliefs about the world (e.g., nature), rather than a narrow focus on beliefs restricted to specific science topics (e.g., motion). Secondly, world view research is concerned with knowledge in cultural context, rather than knowledge in isolation. Cultural context subsumes two ecologies. The first is conceptual ecology consisting of "cognitive artifacts as anomalies, analogies, metaphors, epistemological beliefs, metaphysical beliefs, knowledge from other areas of inquiry and knowledge of competing conceptions" (Strike & Posner, in press). Thus, conceptual ecology is about individuals. The second ecology is about the social and physical milieu in which individuals live. Neither ecology has any meaning without the other. Knowledge of either ecology assists one to understand the other. Of importance in education is the role of world view in learning. Briefly stated, meaning is grounded in a person's fundamental understanding of the world. When a student constructs knowledge such that the knowledge is personally meaningful, that construction will be consistent with the person's world view.[6]

Different Views of the World

It is instructive at this point to examine the issue of world view from a more concrete perspective lest this discussion become too abstract. Figure 3 is an iconographic visualization of the relation between two hypothetical, student world views and a piece of scientific knowledge as presented by a teacher or textbook. "A" and "B" in Figure 3 represent the contours of two different world views, one called the curved world view and the other the angular world view.

Insert Figure 3 about here.

The representation is of fundamental presuppositions. Note that the goodness of fit between the curved world view and the structure of the knowledge to be learned is quite poor, thus, one of two unintended outcomes of instruction is likely. Students will construct meaningful knowledge. However, because meaning is in reference to student world views, the constructed knowledge may be strikingly different from the structure intended by the teacher or textbook author. This is consistent with the findings of MC research (e.g., Novak, 1987). It is also consistent with Chomsky's (1966) description of surface and deep structures and his assertion that surface structure (in this case the intended result of instruction) is reconstructed along the lines of an individual's deep structure.[7] As an example, consider how the reductionism of BSCS textbooks could be received by some religiously oriented students. It would not be at all unreasonable for some students to radically reconstruct the textbook information in terms of a religious view such as scientific creationism. An alternative outcome, and perhaps an outcome more damaging to the cause of science education, is that students simply memorize verbatim what information they can with little or no meaningful learning having taken place. Hawkins put his finger on the problem when he noted that for a child whose experiences have all been geographical, the earth surely does not go - no matter what the teacher says!

The situation is different for students entering with the angular world view. The angular world view is fundamentally compatible with the structure of the knowledge to be learned, though not necessarily isomorphic with the presuppositions of the science curriculum. For example, Cobern (1991b) indicates that some students edit out presuppositions such as extreme reductionism. At the same time, these students construct what would appear to be authorized science, but grounded in their own view of what the world is like, for example a theistic or aesthetic view of the world. Of course, a compatible world view does not guarantee learning. Teachers often must deal with competing conceptions. Nevertheless, one has confidence that the intended learning can take place because the new knowledge is fundamentally compatible with the students' world view. It is in this situation that one can expect the conceptual change model to be most effective. For a different, yet corroborating, point of view see Lemke (1990).

And just what are the science teacher and textbook saying? When educators ask questions about science education the focus tends to be on education, rather than science. On this point, Ogawa (1991) observed, "the American approach to multicultural science education is problematic. It seems to me that the movement encourages 'universal science for all Americans' without ever considering the possibility of multi-sciences," where multi-science refers to science in various contextualizations. Now this is the essential point. Students exist in context, and they bring their contexts to the classroom. Science also exists in context, and in the classroom it is contextualized by the teacher and textbook. One should not automatically assume that it is only student context that is of legitimate concern. To do so is to take the Ptolemaic position that education problems can be solved by adjusting and adding epicycles, when it is quite possible that what is needed is a Copernican reformulation of what science is about, for example, reassessing the role of reductionism.[8]

Contrasting Contextualizations of Science

To further decrease the abstractness of this discussion, Figure 4 characterizes science instruction for each of the seven logico-structural, world view categories. This description is

Logico-Structural Categories	Science Instruction Descriptors	Alternative View Descriptors
The Other	materialistic exploitive reductionistic	holistic social\ humanistic aesthetic religious
Causality	mechanistic teleonomic	mystical teleological contextual
Relationship	objective nonpersonal	subjective personal
Self	dispassionate independent rational	passionate dependent intuitive
Time & Space	abstract formalistic	participatory medium tangible

Figure 4. Example Descriptors for Logico-Structural Categories

based on research that critically examined the cultural form in which Western science is embedded (e.g., Capra, 1982, Merchant, 1989; Skolimowski, 1974; Whatley, 1989), and is employed here only as an example. Nevertheless, there is considerable research that suggests this is a relatively accurate description of Western science education (Kilbourn, 1984; Proper, Wideen, & Ivany, 1988; Odhiambo, 1972; Ogawa, 1989; Ogunniyi, 1988). Thus, it can be argued, for example, that the scientific view of the world (i.e., all that is Other than one's Self) as presented in the classroom is often materialistic, reductionistic, and exploitive. In contrast, students may bring a holistic view of the world with a focus on social and humanistic aspects of the world. Or, the scientist of the classroom is the stereotypical dispassionate, objectively rational man. Some students, on the other hand, may be people who are quite passionate and who blend rationality, emotion, and intuition- and they may not be male. The iconographic portrayal in Figure 3 shows two extremes, total incompatibility and total compatibility. As one considers the two descriptions in Figure 4, one can envision how a student's world view can be a mixture of elements represented in the two columns. In a typical classroom setting, reality for a student is likely to be something between total incompatibility and total compatibility with science and science instruction. Research addressing these issues is in its infancy (Cobern, 1991b; Ogawa, 1989).

This analysis has at least two implications for science instruction. One is that the form science instruction gives to science must be examined (e.g., the reductionism in BSCS textbooks). How does the teacher's world view influence the form given to science during instruction? Is any particular form necessary? How well do various forms fit the students? Can a particular form be adjusted to better accommodate the students? The second is that teachers must consider the possibility of teaching intended to influence students' world views. Of course, it is not uncommon for science educators to claim the inculcation of a scientific world view as a science education objective. However, this clearly represents a naive understanding of world view (Cobern, 1991a). Teaching to influence world view is a far more complicated issue than typically supposed, because world view is an inclusive concept referring to fundamental presuppositions (beliefs) affecting all of one's life situation, not just the science classroom. From the literature it is clear that changing student ideas is difficult whether an idea is about the nature of science (e.g., Lederman, 1986) or about concepts in physics (e.g., Clement, 1987). If it is hard to change the conceptions, the surface structures, surely it is even harder to change the foundations upon which the conceptions are built, the deep structures.

Knowledge and Belief

Influencing student world views is problematic for another reason. It involves changing student beliefs. Although, in one sense, all of teaching intends to change student belief, given that knowledge and belief are intimately related, science educators observe an unwritten distinction between types of belief. Belief can be relevant to science, and thus within the purview of science instruction, or irrelevant and not within its purview. For example, the intent of teaching about evolution is to change student belief about origins, but not student belief about the existence of God. What a world view theoretical perspective implies, however, is that this facile distinction is an educator's artifact. What is irrelevant to the educator or the scientist can be of utmost relevance to the student.

Of course, empiricists would argue that there is no problem here at all because knowledge requires clarity of vision, not faith. Empiricists assume that knowledge conforms to objective reality, with verification serving as a guard against any subjectivity introduced by the senses (Staver, 1985). Whereas knowledge for the empiricist implies certainty, belief implies doubt. For the empiricist, doubt does not apply where empirical verification is possible. Thus, there is an iron clad distinction between knowledge and belief. One knows about evolution because knowledge about evolution is empirically verifiable. One has beliefs, but not knowledge, about God because purported knowledge about God cannot be empirically verified (at least not in any fashion, e.g., Peacocke (1984), acceptable to the empiricist). Doubt is the essential difference.

In constructivist epistemology, the empiricist's distinction between knowledge and belief evaporates because knowledge is no longer insulated from doubt. One could argue that knowledge is thesis, in essence a belief, supported by lines of evidence with the critical question being "whether [one] ought (epistemologically speaking) to hold such beliefs... Epistemology is fundamentally concerned with this normative dimension of belief" (Kitchener, in press). However, there is no unambiguous ontological distinction between knowledge and belief (e.g., belief lacks a normative dimension until it is supported by lines of evidence whereupon belief becomes knowledge) unless one relegates belief to only that which is held blindly. From a world view theoretical perspective, the concept of blind belief is not helpful because people simply do not hold beliefs for no reason.[9] As Saint Augustine once wrote:

> No one believes anything unless one first thought it to be believable... Everything which is believed should be believed after thought has preceded... Not everyone who thinks believes, since many think in order not to believe; but everyone who believes thinks (quoted in Neuhaus, 1990, p. 15).

One may question the epistemological soundness of another's reasons, but not that the reasons exist. This is, of course, the very question asked of knowledge, what is its epistemological soundness? For all practical purposes, belief and knowledge both represent what one has reason to believe is true.

There is, however, a non-ontological distinction that can be made between the concepts of knowledge and belief. The concept of belief implies a degree of commitment typically lacking in the concept of knowledge. For example, a person typically holds his or her beliefs about God with much greater commitment than beliefs about acceleration and motion. This is not to say that commitment is lacking in the domain of scientific knowledge. Lakatos wrote of an "inviolate cluster of hypotheses at the heart of a research program... called the hard core" (Oldroyd, 1986, p. 328) surrounded by a protective belt of modifiable and changeable hypotheses of lessor stature. The constructivist would consider hypotheses at both levels to be knowledge, but obviously knowledge at the core is held with considerable commitment, i.e., a belief by another name.

Confusion arises when researchers use simplistic definitions of belief and knowledge. Belief is knowledge-plus-commitment and can include many conceptions typically thought of as scientific knowledge (e.g., hard core hypotheses). Furthermore, some conceptions are neither belief nor knowledge. They are simply opinion, that is, a thought carrying little commitment and certitude.

The crux of this discussion is that educators cannot continue to observe traditional distinctions concerning knowledge related to science (or belief related to science) and that which is not. Constructivism implies an integrated and holistic view of knowledge. Furthermore, it would be unethical, and probably counterproductive, for educators to take the presumptuous position that <u>all</u> belief and knowledge must conform to science. To be sure, one is faced with a rather disconcerting dilemma on how to treat disparate types of knowledge. However, the analysis presented thus far is not a statement of how things actually are, nor is it intended to drive the development of new teaching strategies. It is intended to raise a good many questions. As Strike & Posner (in press) said of their own theoretical work, this is the presentation of a Lakatosian "<u>hard core</u> of a research program... that [can] be extended in profitable directions by further work." The methodology of that research program is the topic to which we now turn our attention.

Methodological Changes

As noted earlier, the Novak (1977) and Driver & Easley (1978) articles not only influenced changes in research questions, but also stimulated changes in research methodology. Educational research has historically been quantitative. Researchers seek to neutralize the majority of contextual, so called extraneous, variables and then to focus on a very few. Constructivist research, however, has been increasingly influenced by a qualitative research paradigm (Jacob, 1987), particularly ethnographic techniques where the first objective is description for understanding. The descriptive accounts are subsequently used in the formulation of hypotheses, which in turn lead to further interpretive research. The preferred constructivist approach with students has been a Piagetian-styled interview technique called, interview-about-instances (West & Pines, 1985) or phenomenography (Marton, 1988). The interview techniques have become less structured as ethnographic influences have increased and as research has moved from a personal constructivist base to a more contextual constructivist base (e.g., Millar, 1989).

The reason for the change is quite simply the complexity of people. The constructivist has come to understand that the contextual factors positivist researchers seek to neutralize are factors of considerable significance. World view theory suggests that an appropriate research approach to the complexity of human thought and action is ethnographic research aimed at a Geertzian thick description, that is, "an extensive descriptive and interpretive effort at explaining the complexity ..." (Magoon, 1977, p. 652). This complexity that demands thick description also confounds the researcher's inclination to generalize. Cronbach (1975) noted that the simplest of objectives in educational research are often made inaccessible by the complexity of human thought. He suggested that as a researcher examines an effect in different situations, the first task "is to describe and interpret the effect anew in each locale, perhaps taking into account factors unique to that locale ..." (p. 125). Generalizing from any single, local study is risky at best. As Cronbach noted, "when we give proper weight to local conditions, any generalization is a working hypothesis, not a conclusion" (1975, p. 125). Rather, joining Cronbach's suggested local description with Geertz' thick description implies that educational research aimed at understanding the complexity of how students learn science or how teachers teach science should comprise a series of local studies where a thick description is pursued in each locality. Generalizations would then be based on the research series much the same as generalizations in cultural anthropology are often based on several ethnographies rather than one (e.g., Kearney, 1984).

There are numerous publications on the methods of the qualitative paradigm (Brewer & Hunt, 1989; Cobern, 1991a, 1991b; Erickson, 1986; Gallagher, 1991; Glaser & Strauss, 1967; Lincoln & Guba, 1985; Lythcott & Duschl, 1990; Millar, 1989; Smith, 1987; Spradley, 1979). However, to emphasize the importance of adopting a qualitative paradigm for epistemological research consider a recently published study involving student beliefs that was done within a traditional quantitative, empiricist paradigm. Lawson & Weser (1990) examined correlations between purported measures of student beliefs and reasoning skills. The first point to note is that the research involved a neo-Piagetian test of reasoning based on a particular view of rationality. Though this view of rationality is widely held, it has also been criticized for its cultural ethnocentricity (e.g., Cole & Scribner, 1974; Modgil & Modgil, 1982). For example, this view of rationality is based, without qualification or restriction, on the presupposition that "A" cannot equal "not-A." There is no room here for complementary thinking, something that is essential to the understanding of non-empiricist belief systems (MacKay, 1974; Oster & Reich, 1987; Reich, 1990).

The second point is that Lawson & Weser implicitly assumed that as few as two objective items are a sufficient means of comprehending a belief. The research posited belief as discreet, unconnected propositions that can be determined by numerical responses to items such as "The living world is being driven toward greater perfection" (p. 593). The assumption was made without any discussion of sociological or cultural research where the investigation of belief has been a major focus for many years, let alone any admission that a belief could be validated on grounds other than science (Rickman, 1988). For example, the concept of "soul" is simply a scientific misconception. The research evaluated numerical responses for statistical relationships with an equally discreet, unconnected dependent factor. This is a research culture defined by a rather narrow, positivistic view of science. Because many students do not share this culture, it comes as no surprise that the results of the two research instruments were mutually supportive. Ironically, the research supports a conclusion that was not considered by the researchers, i.e., many students do not share significant aspects of the researchers' world view. It is ironic that science education is criticized for promoting rote learning and thus for not fostering formal reasoning, and yet this research employs a factual-recall approach to the study of beliefs. As previously stated, belief has a thesis-plus-support format. When one asks a factual-recall question about a belief (e.g., The living world is being driven toward greater perfection - Agree/Disagree?),[10] one gains no more insight into a person's thinking than had the question been asked, "An electron has a negative charge - True or False?"

In contrast, consider an ethnographic study of college student beliefs concerning the natural world (Cobern, 1991b). This study noted that the literatures of sociology, history, theology, and environmental psychology indicate that historically Westerners are found to hold naturalistic, aesthetic, and religious views of the natural world. The study used an audio-recorded interview format designed to probe for these specific belief types as well as for belief types to be specified <u>a posteriori</u>. The interview transcript analysis showed that informant conversation was often dominated by aesthetic and teleological language. For example:

> I believe in God and I believe that He created nature... if you see a sunset, you see God... nature is aesthetically pleasing, it's something that makes you happy (Cobern, 1991b, Interview 6).

This quote isolated from the balance of the transcript would provide reason to suspect that were the Lawson & Weser belief test given to this student, the result would be many responses that Lawson & Weser consider unscientific. However, the balance of the transcript does not support a conclusion that the student is unscientific. This same student who used aesthetic and teleological language to describe the natural world also indicated that natural science is the appropriate way to explain and understand how the natural world functions.

> If you see a sunset, you see God... but I know there is a reason for the sunset... for example, scientific reasons... There is a way to find an answer to the majority of... questions about nature. You can find out through biology and all the rest of the sciences (Cobern, 1991b, Interview 6).

If one were to isolate these two sets of comments, one would likely predict two different results on the Lawson & Weser belief test, as if there were two different people. However, one does not interpret comments in isolation because a transcript represents a contextual whole. Interpretation of decontextualized data leads to distortion. Yet, that is exactly the weakness of quantitative research.

This is not to say that anyone's interest in the epistemological issues of vitalism, purpose, origins, etc., is misplaced. However, as Lythcott & Duschl (1990) commented on a similar study, research questions must follow from the research paradigm. In a qualitative paradigm the researcher would begin with the assumption that vitalism, for example, like any other concept exists in context and thus is rooted in many aspects of a person's conceptual ecology and social-material culture. The researcher would ask what forms the concept takes. How do these various forms operate in the person's thinking and life situation? What other concepts are influenced? Are any of the influenced concepts related to science? What are those science related concepts, and what is the nature of the influence on them? It is only with this type of thick description that one can avoid the problems of epistemological and cultural chauvinism. Vitalism clearly shows the importance of context because it is a relatively extreme example. The function of an extreme example is to demonstrate that one cannot assume a priori that contextual factors do not operate in less extreme cases.

Conclusion

Constructivist considerations brought science educators to a greater appreciation of the importance of student ideas. Constructivism has also led to an increased awareness that knowledge is connected, a notion that has been profitably exploited with concept maps. Connectedness can be either intra-conceptual, the primary focus of constructivism to date, or inter-conceptual. Cultural studies, including the sociology of science, draw attention to the importance of inter-conceptual issues, that is, epistemological connectedness beyond the "internal affairs" of science. It is this external dimension, the impact of culture on the learning and teaching of science, that world view theory seeks to address.

The new research question, "how do students make sense of the world," is an old question placed in a broader arena. Previous science education research touched on the issues of external affairs when it investigated the influence of economic status, gender, and other personal factors on achievement and attitude in science. These factors, however, were always considered discrete entities to be studied individually while simultaneously attempting to control all other, extraneous factors. Individual factors were never seen as aspects of the seamless web of culture. Culture is the broader arena, and there is research that can guide contextual constructivism. It resides, however, outside of science education. The cultural history of science provides analogies to the notion that science is learned in context. For example, The poetic structure of the world: Copernicus and Kepler (Hallyn, 1990) and Leviathan and the air-pump: Hobbes, Boyle and the experimental life (Shapin & Schaffer, 1985) provide excellent discussions of how scientific ideas arise within a cultural and social milieu (also see Latour, 1990). In anthropology there are highly informative accounts, such as "African traditional thought and Western science" (Horton, 1967) or The domestication of the savage mind (Goody, 1977) of how scientific ideas relate to more traditional forms of thought.

This chapter began by attempting to show that contextual constructivism is a natural outgrowth of personal constructivism. These categories are not mutually exclusive, but complementary. Figure 1 is thus somewhat misleading because the three avenues of constructivism should be brought back together to show that an adequate approach to teaching and learning research includes all three perspectives. While personal constructivism is the anatomy and physiology of constructivism, contextual constructivism is the ecology. Both categories are needed to achieve greater understanding of how students make sense of the world. In turn, this will facilitate the structuring of science instruction so that science makes sense to all students. In 1979, Elliot Mishler used a title that neatly summarizes the case for contextual constructivist research, "Meaning in context: Is there any other kind?" As constructivist thinking has developed since the late 1970s, its proponents have converged on a "no" to Mischler's rhetorical question.

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ENDNOTES

1.. As recently noted by Yeany (1991), at the cost of considerable confusion the term constructivism is variously used in reference to philosophy, epistemology, and learning theory. I strictly use the term in reference to teaching and learning - what one might call pragmatic constructivism in contrast to philosophical radical constructivism and epistemological constructivism.

2.. I use the prefix neo simply to distinguish from classical Piagetian research, research in science education that applies piagetian theory and which typically uses paper-and-pencil assessment techniques.

3.. What the metaphor of construction site does not convey, and which is essential to understand about processes of teaching and learning, is the interactive nature of context and curriculum (inclusive of teacher, textbook, facilities, etc.).

4.. This application of the terms nomothetic and ideographic to Piagetian research is based on Driver & Easley (1978).

5.. Ference Marton of Gothenburg University, Sweden, independently developed a parallel avenue of research called phenomenography, "a research specialization aimed at the mapping of the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of, and various phenomena in, the world around them" (Marton, 1988, pp. 178-179).

6.. This is not to imply that the processes of construction never bring about changes in world view. World views do change. They must if people are to successfully adapt to extreme environmental changes. However, world views primarily have a stabilizing function and should not be expected to change easily or often.

7.. For a different perspective on the concept of deep structure and deep *re*structuring, see Duschl, Hamilton, & Grandy (1990).

8.. I believe that Duschl's (1985) critique of science education curriculum development uninformed by concurrent developments in the philosophy of science supports this position.

9.. This is not to say that one is self-reflectively, conscious of all reasons for his or her beliefs, only that reasons exist although they may reside in the subconscious. Typically, the term blind belief is applied to beliefs where the supporting reason is authority. This is a specious distinction since all of us make use of authority. No one can be an expert in all areas of knowledge.

10.. To be more specific, the instruments involved called for responses on a scale of 1 to 5 representing strongly agree to strongly disagree. There appears to be a considerable spread across responses including the "don't know" response, arguably the only intelligent response to most of the items.