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Constructivism and Non-Western Science Education Research

William W. Cobern
Western Michigan University, bill.cobern@wmich.edu

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Abstract

In this paper, I argue that science education research and curriculum development efforts in Non-western countries can benefit by adopting a constructivist view of science and science learning. The past efforts at transferring curricula from the West, and local development projects that result in curricula only marginally different from Western curricula, stem from an acultural view of science. These efforts also ground science learning in concepts of logical thinking rather than understanding. The resulting level of science learning, however, has not met expectations. Constructivism offers a very different view of science and science learning. It assumes that logical thinking is an inherently human quality regardless of culture, and instead focuses attention on the processes of interpretation that lead to understanding. Constructivism leads one to expect that students in different cultures will have somewhat different perspectives on science. Science education research should inform curriculum projects that incorporate this point, thus making science curricula authentically sensitive to culture and authentically scientific. Japanese elementary science education based on the Japanese traditional love of nature is a good example.

Introduction

Educators have long viewed science as either a culture in its own right or as transcending culture. More recently many educators have come to see science as one of several aspects of culture. In this view it is appropriate to speak of Western science since the West is the historic home of modern science, modern in the sense of a hypothetical-deductive, experimental approach to science.[1] It follows that science education is an aspect of culture and thus it is appropriate to speak of Western science education (Ogawa, 1986; Cobern, 1991). "There is," wrote Wilson in 1981, "a growing awareness that, for science education to be effective, it must take much more explicit account of the cultural context of the society which provides its setting, and whose needs it exists to serve" (p. 29). With respect to Non-western cultures, this suggests that a simple transfer of Western educational practices to other cultures including ethnic minority cultures within the West will not due. Indeed, Lewin (1990, p. 1) noted that today "far more children study science in developing countries than earlier but the evidence suggests that the great majority do not master more than a small proportion of the goals set for them."

Educators tend to focus solely on the careful explication of scientific concepts, the "domestic affairs" (Hills, 1989, p. 183) of science education leading to the view that science curricula are readily transferable. Instead, educators must grapple with how to help students make sense of science concepts that are often quite foreign. This "foreign affairs" focus is based on two premises. All science exists in cultural context, and second, the teaching and learning science is often a cross-cultural activity. By "culture" I have in mind Geertz' definition, "man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs,

[1] If "science" is taken to mean the casual study of nature by simple observation, then of course all cultures in all times have had their own science. There is, however, adequate reason to distinguish this view of science from modern science.

and the analysis of it is not an experimental science in search of law but an interpretive one in search of meaning..." (1973, p. 5). Science makes more than scientific sense to a scientist. It makes sense within the scientist's entire view of reality and significance. A classroom lesson seeks to make scientific sense of a scientific concept, but this becomes a cross-cultural activity when the scientific sense does not automatically fit with the student's more global view of reality. One would think then that the further students are culturally removed from the West the more seriously one ought to address the relevance of culture in science education.

In 1980, Lutterodt noted that to significantly improve science learning in developing nations researchers and educators needed to know more about the influence of local culture on science learning. Ten years later Lewin observed that the profession still had "a long way to go in developing ways of representing science that are not foreign, expert, and culturally unsympathetic" (1990, p. 18). Whether among ethnic minority cultures in the West or in Non-western developing countries, the role of culture in science learning requires greater attention. To date approaches to science teaching amongst the ethnically diverse using transferred, marginally adapted curricula have not been sufficiently effective, and it is time to consider a change of focus. Indeed, Kyle (1993) argued that the embrace and affirmation of cultural diversity in the science classroom is an important theme for science education reform and research. In this article, I argue that researchers can use a constructivist model of learning to both support the need for, and facilitate, investigations of how science education can be formulated from different cultural perspectives. I begin by addressing two widespread though typically implicit assumptions about Non-western and traditional cultures, that is, the assumptions of cultural deficit and illogical thinking.

Rationality is *Not* the Issue

In the West, science is assumed to be an integral part of Western culture. In theory, science is not alien to people of Western culture. What interests Western educators and policy makers is achievement in science, particularly the comparative achievement in science among students of different Western nations plus Japan. Americans are constantly asking whether or not their students know as much science as Japanese and German students, for example. While educators in Non-western, developing nations share an interest in achievement, there are other questions that rarely arise in the West. These are the fundamental questions about one's understanding of the natural world, one's relationship with the natural world, and understanding of causality. These are cultural questions about worldview and the compatibility of various Non-western worldviews with modern science (e.g., Abimbola, 1977; Ogunniyi, 1984 & 1988).

The science historian George Basalla wrote that the establishment of independent, indigenous science in a society new to modern science requires that "resistance to science on the basis of philosophical and religious beliefs... be overcome and replaced by positive encouragement of scientific research" (1967, p. 617). "It is difficult," according to Poole (1968, p. 57), "to see how the less advanced societies can achieve the high living standards at which they aim without assimilating large portions of the Western conceptual system, not least those concepts of scientific significance." Musgrove (1982) not only concurred, he further argued that a successful education lifts children out of their culture. Such opinions reflect an unnecessary "deficit" or "culture-clash" view of culture where traditional cultures are not simply viewed as different, but tacitly assumed to be less rational than modern Western culture.

To date, Piagetian developmental theory has been the framework of choice for most cross-cultural research in education. However, developmental theory has never quite escaped the charge that it is provincially Western (Modgil & Modgil, 1982) since Non-westerners typically do not perform as well as Westerners on Piagetian based tests of reasoning ability. The problem stems from a paradoxical relationship between logic and understanding. Piaget designed a set of clinical interviews based on formal propositions of logic. He inferred levels of cognitive development from performance on interview tasks. For use in education research, others have designed paper-and-pen assessments of reasoning ability based on Piaget's clinical interview procedures (e.g. Lawson, 1978). In either case the inference is that a person is logical if he or she can successfully complete the assessment tasks. These devices, however, involve the research with a rather problematic assumption. To assess reasoning ability the researcher must first assume that the premises of the assessment procedures are correctly understood by the subject being assessed.

Taking as opposite tact, Smedslund (1970) noted that this assumed understanding can only be determined by "Observing agreement or disagreement as to (1) what statements are <u>equivalent with</u> the given one, (2) what is <u>implied by</u> the given statement, (3) what is <u>contradicted by</u> the given statement, and (4) what is <u>irrelevant to</u> the given statement" (p. 217). Here lies the difficulty. If the subject cannot reason logically, the subject will not be able to note equivalence, contradiction, implication, or irrelevance, leaving the researcher unable to determine whether the subject actually understands the premises of the task. Thus, in order for the researcher to measure use of logic the researcher must make the counter-intuitive assumption that the subject <u>understands</u> what is going on. "In conversation," noted Smedslund (1970, pp. 217-218), "we always assume that the other person is logical... When our expectations are not fulfilled, we normally attribute it to a lack of understanding on our part... but not to genuine illogicality on his part... logic must be presupposed, since it is characteristic of any activity of any integrated system and is a part of the very notion of a person." Moreover, if the researcher persists in the counter-intuitive assumption of understanding, there remains a further dilemma. As noted understanding requires that one be logical, that is that the subject be able to note equivalence, contradiction, implication, or irrelevance. In effect, the research assumes what is being tested.

In recent years, numerous Western scholars have turned to misconception and alternative framework research. The researcher probes for understanding, implicitly assuming that the subject is logical. If this reversal of assumption and variable is tenable <u>within</u> Western culture, how much more tenable must the reversal be for cross-cultural research? In cross-cultural research involving Western derived developmental theory and its measures of reasoning ability, for a researcher to assume understanding virtually assures a negative finding. Abiola (1971, p. 63) concurs. "In many investigations, including those conducted by Africans, the imported research instruments... have been taken out of the conceptual context in which they were developed... If you use a culture-bound normative instrument, you end up with a better/worse comparison inference or "explanation"; in most cases it is worse." To be otherwise in such research, the Non-western subjects would need to have acquired the particular understanding assumed by the Western oriented theory.[2] That this will happen, is the implicit assumption undergirding the straight transfer of curricula. Students must conform to a particular understanding to avoid the label of irrationality. For example, Okebukola & Jegede (1990) concluded that Nigerian "rural communities... are apt to explain naturally occurring phenomena through <u>irrational</u> means" (p. 666, emphasis added). The rural students in the study were deemed irrational because of low scores on a Western based measure of reasoning ability. To no surprise the researchers found that the students held illogical ideas. The renowned anthropologist Franz Boas would have had a very different view, "the traditional and customary beliefs of a society provide no evidence about the way individuals think. Beliefs that an outsider considers bizarre are not evidence of bizarre thinking. They tell us something about the social tradition... about patterns of thought, which are a social product" (quoted in Musgrove, 1982, p. 70).

Horton (1967a&b) and Elkana (1977) concur. They argued persuasively that the cognitive activity of traditional cultures is far from primitive though clearly not scientific in the modern sense. Jean Lave's studies of mathematical problem solving among African's involved with traditional trades empirically corroborate the Horton/Elkana thesis (Lave, 1988) as does other research on everyday cognition (e.g., Hatano, 1990). Traditional culture poses no threat to logic and thus on these grounds need not be view as an impediment to the learning of modern science. In contrast, studies such as Okebukola & Jegede (1990) make no attempt to understand how a purportedly superstitious explanation of a phenomenon might be eminently reasonable from within the person's indigenous culture. Logical thinking in this research, and many others, assumes a Western-based understanding of phenomena. Clearly, anyone who maintains a culturally specific view of the world is not going to score well on these measures of logic. This is unfortunate because the promotion of science learning does not require a focus on logical thinking, but a focus on understanding.

Cultural Issues and Curricular Adaptation

Garrison & Bentley (1990, p. 188) called the decade of the 1960s the "golden era" of North American and European science education curriculum development. Prather (1990, p. 12) called the events of the 1960s a "revolution in science education." UNESCO and other governmental agencies arranged for the transfer of many of these curriculum developments to Non-western, Third World nations to aid technological development and modernization. The prevailing attitude toward the transfer of scientific knowledge was little concerned with culture. "A literate nation," wrote Lord (1958, p. 340), "is provided with the means for substituting scientific explanations of everyday events - such as death, disease, and disaster - for the supernatural, non-scientific explanations which prevail in developing societies..." Through education, modern science is brought into developing societies where it can displace nonscientific ideas.

Early on, Champagne & Saltman (1964) noted that transfer should not occur without first adapting curricula for the receiving country. Curricula, "would have to be adapted to remove an American cultural bias and substitute an African cultural bias" (p. 1), they wrote. However, all too often educators held naive views about adaptation. Cultural adaptation simply meant changing to "terms of tropical ecology and meteorology, and increased rates of reaction in the warmer climate [and substituting] Lagos for London, cedis for dollars, mangoes for apples" (Wilson, 1981, p. 27). On this point, it is worth quoting at length from Dart & Pradhan (1967, p. 649):

> Science education, in any country, is certainly a systematic and sustained attempt at communication about nature between a scientific and a nonscientific, or a partially scientific, community, and as such it should be particularly sensitive to the attitudes and presuppositions of both the scientist and the student. In fact, however, the teaching of

> science is often singularly insensitive to the intellectual environment of the students, particularly so in developing countries, where the science courses were usually developed in a foreign country and have undergone little if any modification in the process of export. Why should we suppose that a program of instruction in botany, say, which is well designed for British children, familiar with an English countryside and English ways of thinking and writing, will prove equally effective for boys and girls in a Malayan village? It is not merely that the plants and their ecology are different in Malaya; more important is the fact that the children and their ecology are also different.

Dart & Pradhan (1967) recognized a need for cultural sensitivity that goes far beyond the simple substitution of examples. Odhiambo (1972) concurred.

Nevertheless, in 1980 Lutterodt virtually admitted that this had not happened. In an article about curriculum adaptation based on situation variables, Lutterodt (1980) observed that "situation" typically meant school structure, local resources, and local physical environment. For example, he commented on "the scandal and irrelevance of African pupils being taught the structure of the buttercup, rather than that of the hibiscus" (1980, p. 128). Important, yes, but still superficial in light of the Dart & Pradhan (1967) comments. Based on his extensive research in Papua New Guinea, Maddock (1981) called for a more anthropological approach to science education. Yet, six years later, Urevbu (1987) observed that concerns about cultural sensitivity in science education had yet to be heeded. Lewin repeated this observation in 1990. Lewin (1990) noted that at the end of the 1980s indigenisation had succeeded to the point that most former colonial nations had developed their own science programs, but too often indigenisation continued to mean the superficial adaptation of essentially Western curricula. The profession still has "a long way to go in developing ways of representing science that are not foreign, expert, and culturally unsympathetic" (Lewin, 1990, p. 18). Science textbooks from around the globe remain strikingly similar (Altbach, 1987; Apple, 1992). Some similarity is to be expected. For example, one expects a discussion of the observed phenomenon known as photosynthesis to appear in all basic biology textbooks regardless of cultural location. However, science is far more than a distilled and purified set of objective facts that compel acceptance. It is no longer tenable for a teacher to claim that he or she is teaching only science (Fourez, 1988; Eger, 1989). It makes sense that an isolated scientific concept (e.g., photosynthesis) is *a*cultural, but not the milieu in which the teacher, textbook, or curriculum situates the concept. About textbooks, Apple wrote:

> They signify - through their content and form - particular constructions of reality, particular ways of selecting and organizing that vast universe of possible knowledge. They embody... [a] selective tradition - someone's selection, someone's vision of legitimate knowledge and culture, one that in the process of enfranchising one group's cultural capital disenfranchises another's. (1992, p. 5)

The degree of similarity among science textbooks and curricula across cultures is thus unwarranted.

Assumptions about knowledge and reality, values and purpose, people and society that undergird modern science are grounded in Western secularism. This point has been thoroughly addressed by those interested in feminism, culture, and religion (e.g., Deloria, 1992; Johnson, 1991; Whatley, 1989) However, curriculum adaptation too often as simply meant the exchange of textbook examples or photographs (e.g., wheat to rice or white scientist to black), without addressing underlying assumptions. The failure to recognize the need for authentic cultural sensitivity with regard to these assumptions has led Third World science education into social difficulties. In a series of studies between 1972 and 1980, Maddock (1983) found that science education in Papua New Guinea had a significant alienating effect that separated students from their traditional culture, "... the more formal schooling a person had received, the greater the alienation..." (p. 32). Holmes (1977) and Wilson (1981) had similar findings. At a conference in Nigeria, Thijs (1984, p. 37) noted that "science is indeed an issue for a social debate. Too often it is naively absorbed without considering the cultural implications."

The good of any nation or society involves several, often competing, interests. The good is rarely based on a single issue even one as important as the advancement of scientific learning. However, the advancement of science and science education often competes with national interest in maintaining the integrity of traditional culture. It is thus necessary to ask about the balance between these two interests, science and culture. One should ask to what extent efforts to promote scientific literacy in Non-western nations have <u>inadvertently</u> and <u>unnecessarily</u> promoted a Western, or otherwise alien, world view? Among other African scholars, this interest is shared by Fafunwa (1967), Kalu (1980), and Mazrui (1980), and by UNESCO (Apea, 1993; also see UNESCO, 1989).

I take to task the implicit assumption in much of the literature that Non-western, non-scientific ideas are inherently irrational, an assumption grounded in the positivist ideology that scientific thinking is the ultimate measure of rationality (Adas, 1989). People do not believe things that do not make sense. They believe precisely because sense <u>is</u> being made - because there is rationality. A reader would be mistaken to infer that this discussion is soft on superstition, or that science is being reduced to an aspect of cultural relativism. I agree with Matthews' (1992, p. 14) comment that, "many ideas and constellations of ideas can 'make sense' for an individual, and this has absolutely no connection with their truthfulness or legitimacy. Constructivists reasonably point out that teaching truths that simply do not make sense to individuals, and that forever remain foreign to them, is hardly good pedagogy; but there is a middle ground between this and endorsing ... the claim that just making sense is the goal of education..." My view is that <u>there is</u> middle ground to be discovered but it will not be discovered if the focus of attention is always on the matter of traditional culture and its potentially <u>adverse</u> influence on science education. This is a frequently cited concern in the literature (e.g., Gallagher & Dawson, 1986; Jegede & Okebukola, 1988; Mohapatra, 1991), and is the focus of Matthews' comment above.

Science content is science content regardless of culture to be sure, but not so with its communication. Communicated science, which includes science education, is inculturated (Apple, 1992). In the jargon of education, there is always a <u>hidden curriculum</u>. This raises two issues, which have received little attention. The first issue is the potentially adverse influence of an alien hidden curriculum on the integrity of a traditional culture. The second issue concerns the potentially adverse influence on science education among those who are alienated by an alien hidden curriculum. We may not understand the complexities of culture change and adaptation, but culture does change. Any new idea brings change as people in the host environment react and adapt to the new idea. Modern science will influence a Non-western culture as surely as it has influenced Western culture. My concern is not about cultural change per se, but about unwarranted influence. Must African nations, for example, adapt to science and adapt science to African culture exactly as the West has done? To what extent can science be taught without the cultural dress of the West? To what extent does Western garb inhibit the learning of scientific concepts? What cultural changes are necessary for effective science learning? What changes are unnecessary? These questions arise because, relatively speaking, modern science and science education are newly imported phenomenon in the cultures of most developing countries - and for the most part, imported in Western packaging (Ladriere, 1977). To effectively address these questions, researchers must have a view of learning that is <u>transferable across</u>, and <u>appropriate for</u>, different cultural environments. Constructivist thought supplies this view.

Constructivism

In marked contrast to developmental theory, <u>constructivist theory</u> facilitates a focus on understanding. Constructivism is a model of how learning takes place (Yager, 1991), rather than a theory of how rationality develops. The focus of constructivism is the content of thought rather than the formal operations of logic that thought can involve. Yeany (1991, p. 1) alluded to a Kuhnian paradigm shift and suggested that constructivism may lead "to a gelling of existing thought as well as the stimulation of new ideas." The existing thought includes Piaget's concepts of accommodation and assimilation, Ausubel's concept of meaningful learning, and post-empiricist philosophies of science. Moreover, one the attractions of constructivism is its utter simplicity. On reflection one would almost say the notion is patently self-evident. However, the widespread adoption of the term constructivism in various areas of education has actually created considerable confusion and controversy. For all its simplicity, the term is defined differently by different people. Many take a rather pragmatic approach to constructivism. They focus on constructivism as a description of learning that can be turned about and used to guide teaching. Much of the research on models of conceptual change is pragmatically oriented (e.g., Driver, 1989; Osborne & Wittrock, 1983). Ernst von Glasersfeld (1989) has argued for the more philosophical view that constructivism is essentially an epistemological commitment to instrumentalism grounded in philosophical idealism. For him and other <u>radical</u> constructivists, it is fundamental that "cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality" (Wheatley, 1991, p. 10; also see Tobin, 1991). So, what is constructivism?

The literature is not without good theoretical articles on constructivist theory (e.g., Glasersfeld, 1989; Wheatley, 1991), and I do not need to repeat those discussions. Rather, in an effort to foster an intuitive grasp of constructivism, what follows is a descriptive narrative. The intent is to evoke, in somewhat abductive fashion, an understanding of learning that is <u>transferable across</u>, and <u>appropriate for</u>, different cultural environments. I believe that this is best done by focusing on the post-empiricist roots of constructivism.

All peoples in every culture wish to know about the world around them, whether one speaks of the world in physical, social, or even spiritual terms. Science of course is a discipline that tells us about the physical world, and in modern science one's senses are critical. One uses sight, hearing, feel, and taste to learn about physical phenomena. Instruments as simple as an ordinary ruler or as complex as a radio telescope or mass spectrometer extend the range of basic human senses. The naive view of empirical science is that human senses provide authentic data corresponding to the real world. Experimentation keeps subjectivity in check. But, is that really how our senses work? Consider that science exclusively focuses on measurable sensation. For example, a physicist typically is not nearly as interested in the color of an object as he or she is in measurable electromagnetic wavelengths emitted or reflected by the object. If you want to build a color television, knowledge of electromagnetic wavelengths is necessary. However, who can say that a wavelength of 4.0×10^{-7} meters says any more about the <u>reality</u> of an object than does blueness? In fact, philosophers of science tell us that there is no answer for this question. Scientists focus on measurable attributes simply because they have chosen to do so - it works for what they want to do.

There is another question that confronts human efforts to understand reality, regardless of the physical attributes on which one chooses to focus. How do we know that the objects of perception are actually there as perceived? As early as 1604, Kepler demonstrated that the physical image on the retina of the eye is inverted. Yet that is not how we perceive objects. We perceive them right side up. In other words, even though we <u>see</u> and object upside down, we nevertheless <u>perceive</u> it right side up. How then can we say that what we perceive is actually what is there? Perception appears to involve interpretation rather than simple transmission. To further illustrate the difference between sight and perception try to image a person born without functioning sense organs. Somehow the person survives and one day after many years, the person's eyes suddenly start functioning. His eyes would see reflected light as ours do, but what would he perceive? A mass confusion of light, a jumble of hues and intensities, a tumult of sensation, all signifying absolutely nothing! He would not recognize a tree in front of him because he could not have had any prior knowledge of the <u>concept</u> of tree. Perception is the <u>act</u> of one who sees, not the <u>passive reception</u> of light reflected by objects. To make this more personal, I spent my first year in Nigeria going from one faux pas to the next because I simply did not understand much of what was going on around me. On the other hand, my Nigerian colleagues who had studied in America would roar with laughter recounting tales about their first exposure to American culture. This illustrates what modern developments in the philosophy of science have clearly shown, all observation is theory laden.

There are then two profound limitations on scientific knowledge. First, science is limited by its focus on selected attributes to the exclusion of others. This is a choice made by scientists not a limitation imposed upon science by physical reality. Second, one can perceive an object only when one has preexisting knowledge of what is being examined. The result is that the scientist cannot say that he or she has exact knowledge of what reality is like. Rather, the scientist drawing upon previous knowledge interprets experience following rules agreed upon by the community of scientists. A scientist constructs knowledge to fit experience and that knowledge is fallible by virtue of lacking exactitude and comprehensiveness. Ultimately, one can never know for sure how close knowledge approximates reality. Rather, knowledge is a meaningful interpretation of one's experiences of reality, where "meaningful" means that the interpretation is externally bounded by experience and internally by what makes sense to an individual or community of individuals. Instead of a photograph of reality, scientific knowledge is much more like an artist's impressionistic painting of reality. Here lies the link with the teaching and learning of science - within and across culture.

If there were a direct link between the scientist and a physical reality independent of the scientist, one could argue for a direct link between scientific knowledge independent of any knower and the acquisition of scientific knowledge by a learner. "This follows from the principle that the appropriation of knowledge demands cognitive performance similar to the original acquisition of that knowledge" (Eger, 1989, p. 90). Direct linkage is the viewpoint of naive realism. It implies that knowledge can have an existence independent of a knower. It, thus, implies that teaching is best done by careful, methodical, detailed explication of scientific knowledge with the expectation that students will learn by receiving (i.e., memorizing) the knowledge. In fact, under the influence of positivism which taught that rationality and objectivity resided exclusively in quantitative experimental science, that is exactly how science has been taught for many years (Duschl, 1985). Moreover, this viewpoint supports curriculum transfer since it does not recognize any significant cultural influence on science.

However, if scientific knowledge is a scientist's meaningful construction based on his or her experiences of reality, how can the learning of scientific knowledge be any different? If I cannot know reality for sure, what is it that I am learning when I learn? In one very important aspect, there is no difference between the original derivation of scientific knowledge by a scientist and the learning of scientific knowledge by a student - both are acts of interpretation. When I learn a science concept I am constructing a personal understanding of the concept based on what I perceive the textbook, or activity, or teacher to be saying. Just as a scientist interprets experience in light of a personal background of knowledge, I learn by interpretation in light of my personal, culturally embedded, background of knowledge. In contrast, rote memorization involves no interpretation and is rarely meaningful; and therefore, students soon forget most of what they memorize.

Constructivism is an apt metaphor. Learning is the active process of constructing, or putting together, a conceptual framework by a process of interpretation. No one learns science by transmission - at least not meaningfully. Consider the following simple dialogue:

Teacher:	I say to you the man is coming.
Student:	I hear you say that the man will be here in a few minutes.
Teacher:	No, the man will be here tomorrow.
Student:	Now, I understand that by the word "coming" you do not mean coming "right now."
Teacher:	Yes, but you are saying that for you "coming" means coming now.

Both teacher and student are learners trying to understand how the other interprets the meaning of "coming." Each has to build a concept version of "coming" that makes sense to the builder while appearing to correlate with the other's concept. The teacher cannot communicate effectively unless he or she comes to an understanding of the student's viewpoint, i.e., that the student interpreted "coming" to mean "coming right now." In constructivist thought, it is fundamental that learning involves negotiation and interpretation influenced by prior knowledge. Moreover, successful communication requires a threshold of shared prior knowledge.

In science education, it is of considerable significance that the researcher can use constructivism and meaningful learning to help make sense of a widespread occurrence among people. It is widely reported in the literature that people hold many different ideas about phenomena such as motion, force, life, and gravity (e.g., Helm & Novak, 1983; Novak, 1987). These are often commonsense ideas that frequently differ from accepted scientific viewpoints even when the people are students of science. A science teacher carefully explicates a concept, yet students still come away with quite different interpretations of that concept. Clement (1982) found that even graduate level physics students held views of the concept impetus that varied considerably from the scientifically orthodox view. If learning occurred by transmission rather than construction, learners would either have a concept, a piece of it, or nothing at all. What they would not have are idiosyncratic versions of a concept.

Common experience clearly demonstrates that meaningful learning for some students takes place when instruction is didactic and direct. Constructivism avers, however, that this happens because an individual student has been able to make sense of what the teacher says, not because the teacher made the sense for the student. These students, who can successfully negotiate and interpret scientific meaning with little or no assistance, are the ones teachers consider scientifically-inclined. However, teaching for construction rather than transmission suggests that teaching ought to facilitate negotiation and interpretation based on the learner's prior knowledge. For example, this suggests that discourse between students and teacher and among students will facilitate learning. It also suggests activity, or hands-on learning, by itself is not enough. An otherwise good inquiry lesson will fail for students if the lesson does not allow for a meaningful grappling with the concepts under study. In 1978, Novak pointed out that educators tend to conflate learning and presentation. Presentation of material, by whatever method, never guaranties learning. In summary, constructivism is a model of learning that implies a student is always an active agent in the process of meaningful learning. A student learns not by receiving a transmission, but by interpreting a message. One's interpretations are always influenced by prior knowledge, and a threshold of shared prior knowledge is essential for communication. This raises a question. Is any textbook or curriculum is ever authentically transferable given that a textbook or curriculum written in one culture implicitly, and of necessity, assumes a shared background in that culture?

The Cross-cultural Application of Constructivism

Construction involves interpretation influenced by prior knowledge, and this suggests a conceptualization of scientific knowledge in which it is reasonable to expect culture specific understandings of science. Simply put, one should not expect (say) Nigerian students to understand science exactly the way students in Western countries understand science. Unless their traditional world view has been substantially altered, Nigerians will construct a view of science based on a Nigerian understanding of the nature of human beings and the essence of the natural world, views of causality, space, time, and views of the relationship between human beings and nature (Cobern, 1991). This does not mean they will be unscientific. Rather, their scientific view point will reflect their Nigerian world view, and to that extent, there will be differences. With regards to women's issues, the feminist literature argues that "the problem is not making women more scientific, but making science less masculine" (Fee, 1981, p. 87). Similarly, the problem in Non-western science education is not to make it more scientific, but to make it less culturally Western.

There are several research avenues that bear on science education issues in Non-western countries. The anthropological field of ethnoscience, for example, has included studies of the categories used in traditional cultures for classifying plants (e.g., Berlin, 1972; Behrens, 1989; Altran, 1990). Science education researchers conduct science misconception research, for example, Driver's (1991) comparison of misconceptions across several cultures (also see Hewson & Hamlyn, 1985; Novak, 1987; Thijs, Dekkers, & Smith, 1993). Psychologists study cognition across cultures (e.g., Cole & Scribner, 1974; Hatano, 1990). These avenues of research are highly informative and essential, however, I am addressing the balance between science and culture and the problems specifically posed by science curricula. For example:

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 and curriculum?
5. What happens when student cultures, teacher culture, and the culture of science meet face to face in the classroom?
6. When science is resisted, is it the science people object to or is it the curricular context of the science?
7. When pupils are influenced by science curriculum, are they influenced solely by science? Or, are they influenced by science plus the context in which it is presented?

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 and socio-cultural milieu of students.

An excellent example of the type of cultural research I am referring to is Ogawa's (1989) and Kawasaki's (1990) analyses of Japanese science education and the shizen problem. Like so many other Non-western nations, Japan's efforts to modernize its education system included the importation of Western science curricula which were translated for use in Japanese schools. There are, however, English words which have no direct equivalents in Japanese because the concept named by the word is not found in Japan. For these words the nearest possible Japanese word or collection of words must be used. A case in point is the English word "nature" which of course features prominently in curricula which are about the study of the natural world. The English word "nature" can be translated into any Western language with little difficulty because the West shares a traditional understanding of the concept named by this word. In fact the Western concept of nature has been the subject of extensive discussion (e.g., Glacken, 1967; Merchant, 1989). "In the Western idea," wrote Watanabe (1974, p. 280), "man was not an ordinary part of nature. He was a specially privileged creature, and nature was subordinate to him... He was the master of the natural world, which was at his disposal to analyze, examine, and make use of."

In Japanese secondary science curricula the English word "nature" is translated as "shizen." The problem is that "shizen" does not name the same concept that the English word "nature" names. "[Shizen] for the Japanese," continues Watanabe (1974, p. 280, "[is] different. It [is] an object not of his mastery, but of his appreciation, and [is] even his best companion." Ogawa (1989) and Kawasaki (1990) both note that Japanese elementary science education is designed to promote the quintessentially Japanese objective of fostering "a rich desire to love nature" (Ogawa, 1989, p. 248), that is, it is based on "shizen." On the other hand, Japanese secondary science education uses the term "shizen" but within a curriculum that is similar to

Western science curricula including the Western concept of nature. The success of Japanese education is highly touted in the West and thus Ogawa's assessment of Japanese science education makes for arresting reading. "It is interesting that this [shizen] type of elementary science is positively accepted by society, by elementary teachers and by parents, as well as by children. In contrast, most pupils do not like secondary science" (Ogawa, 1989, p. 248). Ogawa and Kawasaki attribute the difference to the "shizen" orientation of Japanese elementary science education.

I reiterate. I am not suggesting that there is a Japanese science, an American science, an African science and so on, and that each is unique. I am referring to the culturally influenced webs of meaning in which science is embedded and which varies both the appearance of science and the understanding of science from culture to culture. There are of course great similarities, and scientific concepts will, in turn, influence local cultural views. The importance of constructivism is first that it allows one to see the naturalness of variation. Second, it provides a promising direction for research, specifically, the exploration of cultural and metaphysical issues that are at the heart of understanding. Research must illuminate what it means to understand science from different cultural perspectives. It is thus crucial to ask what a uniquely African, Arabic, Asian, or Latin perspective in science might be like, and how such perspectives can be incorporated into the science education of African, Arabic, Asian, and Latin countries.

Concluding Remarks

Interest in cultural issues among educators is clearly not new and there have been some interesting attempts at making curriculum culturally appropriate. Vlaardingerbroek (1990) provides an example from Papua New Guinea, D'Ambrosio (1991) provides an example from Brazil, and Anamuah-Mensah (1993) from Ghana. Not too long ago a seminar was held in Panama "to call attention to, and encourage serious consideration of, influences of cultural background of youth on cognition and learning in science" (Gallagher & Dawson, 1986, p. 1). Whether intended or not, all too often educators write as if culture is an obstacle to overcome.

> In all countries, one of the major educational issues centers on education of youth in science... But most national leaders recognize that education youth in science is not a simple matter. It is complicated by... difficulties in teaching science to many youth, especially those from social and cultural groups whose belief systems are at odds with the belief systems underlying science. (Gallagher & Dawson, 1986, p. 1)

This attitude is grounded in a long history in the West of judging Non-western people with the standards of modern, Western science and technology (Adas, 1989).[2] From a constructivist perspective it is easier to see that modern scientists and traditional people are, in one important aspect, engaged in the same activity. Both are attempting to make sense of the world around them. Rather than focusing on their different conclusions, I would focus on this commonality. As the Soviet scientist Zinchenko (1989) commented, there is no guarantee that science divorced from culture can sustain itself. There is also no guarantee that interest in science once divorced from culture can be sustained among students. In constructivism, the science education research and curriculum development communities have both a model of learning and a view of

[2] Adas (1989) argues that Westerners have long evaluated other cultures by measuring their science and technology against the standards of Western science and technology. Winch (1977) specifically took anthropologists to task for insisting that rationality in other cultures be assessed by the standards of Western science. Also see Horton (1967a & b) and Cobern (1991, pp. 5-7).

knowledge that is authentically sensitive to both culture and science.

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