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Alternative Constructions of Science and Science Education

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Alternative Constructions

I want to begin today with two short personal remarks. My field of research at home is the cultural study of science education. In other words, I am interested in what is commonly called the culture of science and how that becomes interpreted in science education by teacher and curriculum. I am interested in the variation of culture among American students, cultural variations grounded in family and community and brought to the classroom. I am interested in the cultural interactions that are precipitated by the meeting of cultures in the science classroom. In my current work I use worldview concepts to examine the various ways students and teachers have come to understand the natural world and the manner and extent to which science has informed that understanding. I came to this avenue of research from my experiences as a lecturer in science education at the University of Sokoto, Nigeria. My research is grounded in an African experience, and what I have to say today I have said at home. Now I am not naive. I am fully aware of great differences between the two continents - it is simply that I have found that certain themes are of broad geographical importance.

My second personal remark is that I do not think that I have much to say that many of you have not already heard or said. However, I trust that the context of my presentation will stimulate and precipitate new thinking about these known but very important ideas. In brief the ideas are first that educators have historically thought of science as a singularity -being above culture; that however, has led at least tacitly to the view that science education ought also to be a singularity. Indeed, science education around the globe is remarkably similar. The second idea is that regardless of one's position on the singularity of science proper; one ought to consider alternative, culturally-grounded constructions of science education, that is, there ought to be heterogeneity in science education.

Western Science, Western Science Education

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[1] science since the West is the historic home of modern science, modern in the sense of a hypothetical-deductive, experimental approach to science. 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. It follows that science education is an aspect of culture and thus it is appropriate to speak of Western science education. I have noticed in the education literature since the late 70s, "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" (Wilson, 1981, p. 29) This suggests that a simple transfer of Western educational practices to other cultures including sub-cultures within the West will not due. Indeed, statistics indicate 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" (Lewin, 1990, p. 1)

Educators tend to focus solely on the careful explication of scientific concepts, the domestic affairs 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[2] focus is based on two premises. First, 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, 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. And of course there is great interest in cultural issues as can be seen in the literature as well as by the papers being presented at this conference.

Curriculum planners, however, have historically followed the rule of thumb that science education ought to be as much like science proper as is possible. So if science is viewed as a singularity, then so should be the view of science education. Figure #1 is a schematic representation of a strict empirical view of science. Note that science is

shown in the natural world with no connection to the social world. In other words, in this view, which might be called the received view, society has little or no impact on science. Science in the main is a reflection of the natural world. Please note that at the university one can find courses on the comparative study of religion, of art, of politics, of economics - but there are no courses on the comparative study of science. It is often said that there is one nature and therefore only one science.

One Nature, One Science?

Well, is it ever appropriate to modify the noun science by placing an adjective before it? Clearly, there is little disagreement about referring to the natural sciences, the physical sciences, and the like, but what about African science or feminist science? Is there a plurality of sciences in this sense? It is a commonly held opinion that "Only one science exits, and it has no built-in point of view. The weight of the evidence determines the conclusions, whatever they may be" (Shapiro, 1986, p. 256). From this perspective, science is above culture. Cultures vary from location to location, but science transcends culture and is constant across all. It may be that meaning in art and religion is influenced by idiosyncrasies and cultural variations, but not science. In his discussion of the unity of science, a discussion mentioning scientists only from Europe, C. P. Snow (1961, p. 258) said of the great physicist Rutherford, "For him the world of science was a world that lived on a plane above the nation-state..."

This "above the nation-state" or trans-cultural position is implicit in the literature on the transfer of scientific knowledge from modern Western nations to developing, non-Western nations. The eminent Pakistani physicist, Abdus Salam, was adamant that for developing nations "there is only one path to gaining ascendancy in science and technology - master science as a whole. These societies are not seduced by the slogans of 'Japanese' or 'Chinese' or 'Indian' science" (Salam, 1984, p. 285). Within this perspective, a primary concern of science educators is the impediment that deficient, indigenous cultures pose to the introduction of science - which coming **from the West** is not **of the West**. Both science and science education are acultural within this perspective. But, is science really acultural? This question is inevitable when a discussion turns to the spread and growth of modern science in non-Western societies. People, societies, cultures can be very different, and internationally there is a growing rhetoric on the value of pluralism and multiculturalism. Some advocates of pluralism want to extend these values to science, and so they would answer in the affirmative. They would surely go on to argue that this pluralistic nature of science ought to be reflected in teaching both science and about the nature of science.

Scientific pluralism is a logical extension of the strong program in the social study of science that advances a radical social constructivist view of scientific knowledge and method. In Figure #2 one sees the virtual opposite of the received view of science. From the radical social constructivist perspective, science is almost wholly a social construction, little affected by the natural world. I find critical weaknesses in the strong social constructivist position and believe that it would be a grave mistake for any society trying to develop a community of scientists to adopt the strong social constructivist view. This does not preclude one from adopting a strong social constructivist view of science education; and therefore I am cautious about developing science education in the strict image of science proper (see Figure #3). If one adopts a strong social constructivist view of science education then it becomes sensible to think about alternative constructions of science education. Before I go on to do so, however, I want to proceed with the topic of science education based on science as a singularity. In my view this has resulted in two serious errors for science education. One error is the notion of cultural deficit and the other is the notion of a non-rational mind or rationality gap.

Cultural Deficit Theory

The rise of modern science occurred first in Europe and expanded with European culture to what today is the Western world. As a way of denoting geographical location, one may accurately speak of Western science. This says nothing about culture, only geography. Indeed, the empiricist ideal mitigates against any consideration of a cultural influence within science. The empiricist ideal is one of strict objectivism. From this perspective, the goal of science is the complete description of the physical world independent of culture. Moreover, science is independent of persons except that an individual must have a requisite educational background of scientific and

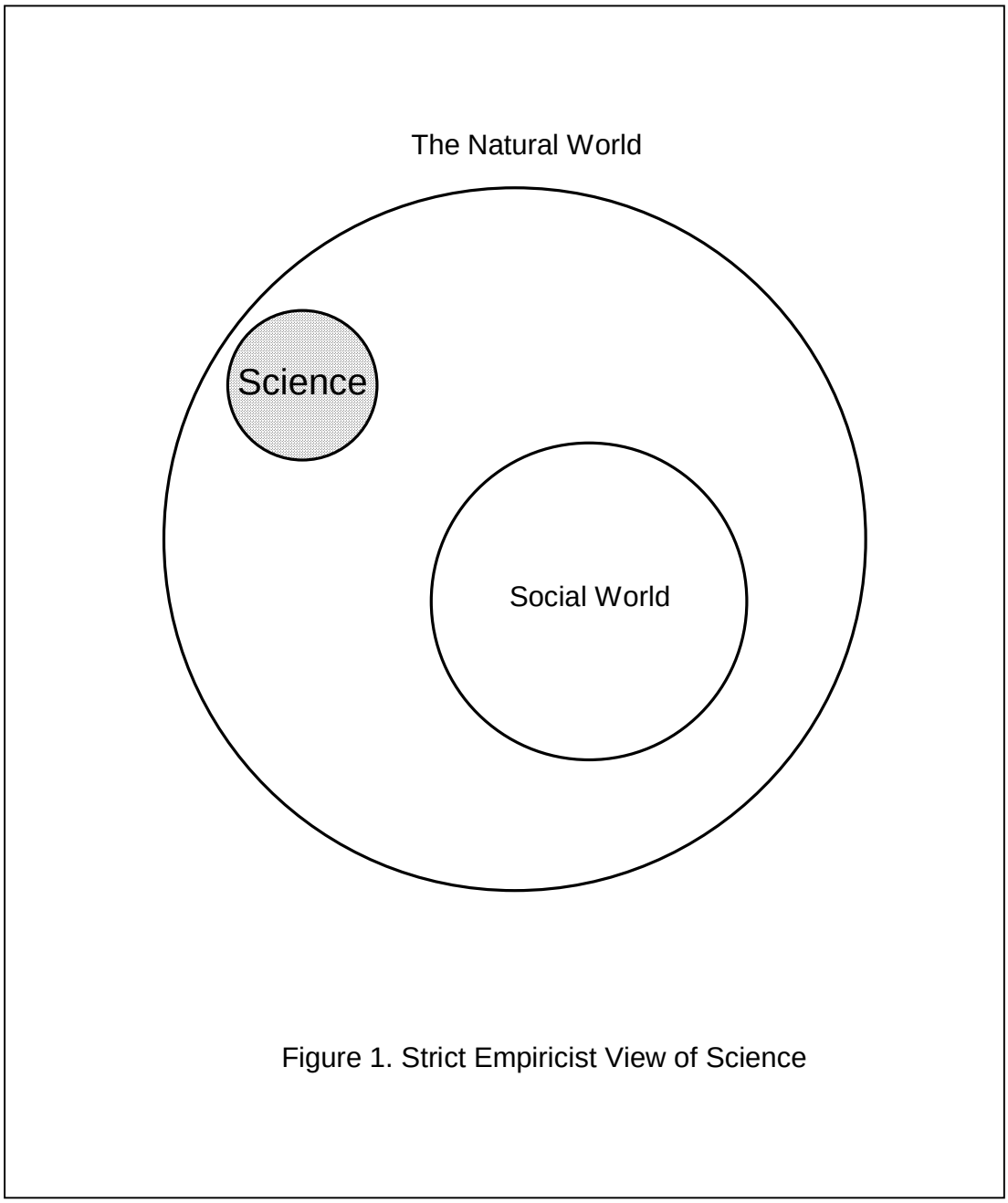

Figure 1. Strict Empiricist View of Science

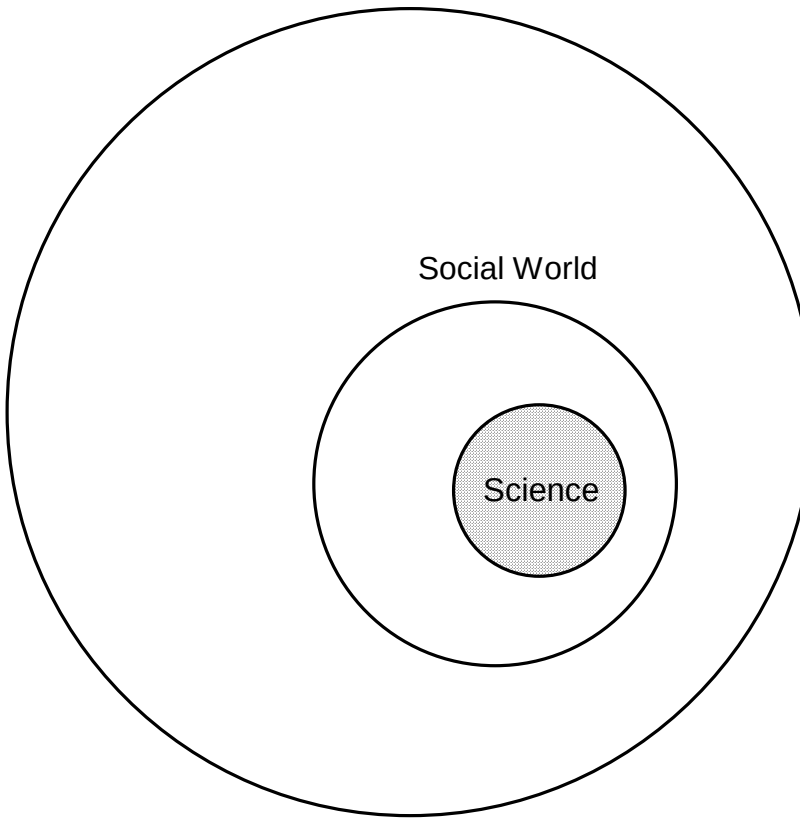

Figure 2. Social Constructivist View of Science

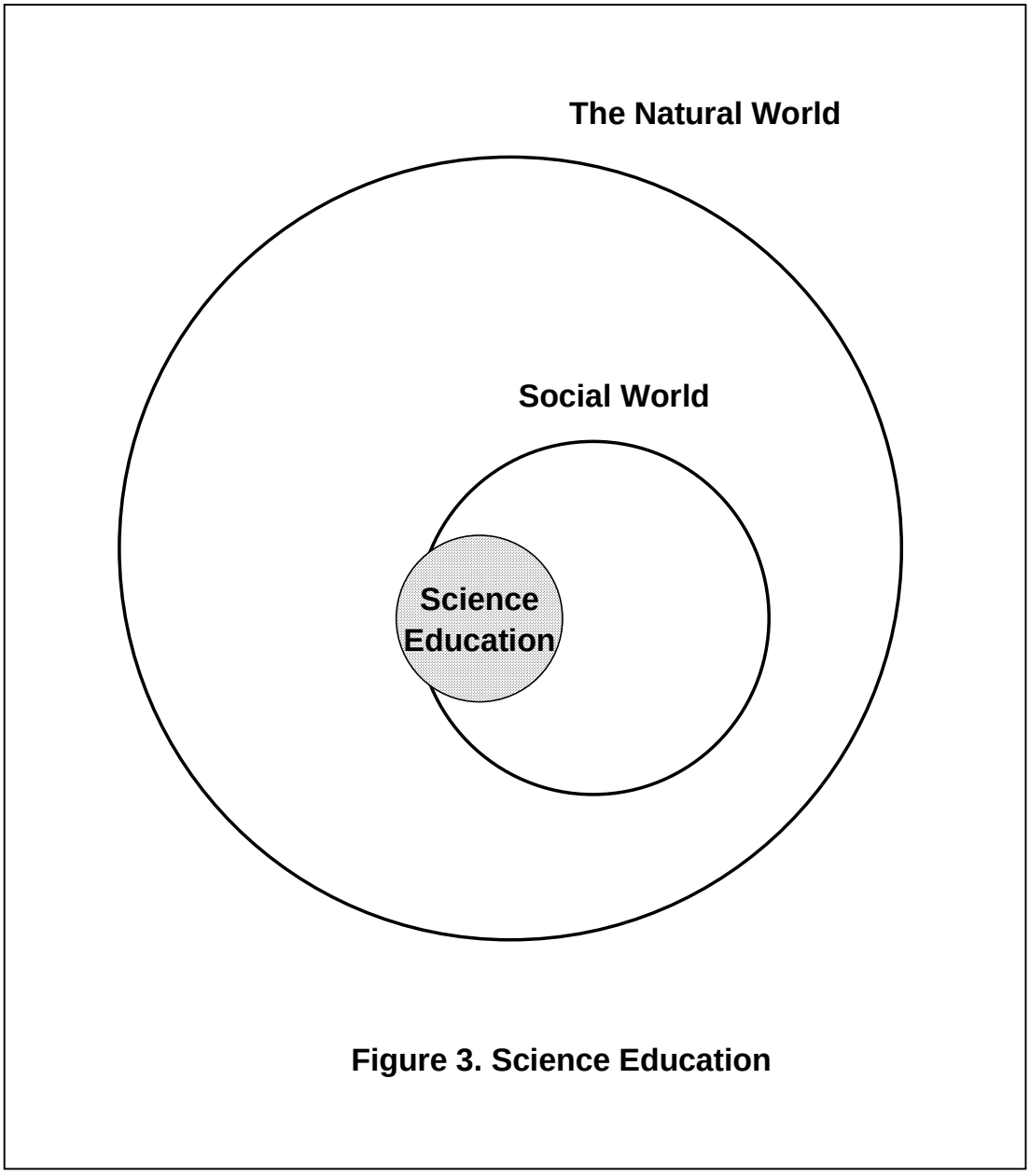

Figure 3. Science Education

mathematical knowledge. Westerners have not thought this a Western view per se, but simply an accurate and appropriate view of modern science (modern as opposed to Medieval and ancient science). Many beyond Western borders agree (e.g., Salam, 1984).

Except for Japan, the spread of modern science beyond Western borders began in earnest with the end of the colonial period. Independence inaugurated a period of feverish developmental activity as newly independent states of the Third World sought to improve quality of life and close the economic gap between themselves and the West. The wisdom of the day argued:

> From... the present state of interaction between scientific research and society, and from the definitions of underdeveloped countries and of cultural revolution..., there follows one basic conclusion on national policy: The building of scientific research in the less developed countries into a social force relatively as strong as it is in the developed countries must have, from the first, a priority as high as, for example, economic development... (Dedijer, 1962, p. 783)

Rostow's (1971) seminal book on development, The Stages of Economic Growth, carried this message of science for economic development to an eager audience. In the main, the way in which governments attempted to implement this perspective on science and economics was to set up a pipeline, so to speak, for transferring scientific and technological knowledge from the West to the developing nations. There was no need to begin an indigenous scientific enterprise from the ground up when one could import a highly advanced corpus of scientific knowledge from abroad. And, of course, science education - also to be imported - was the key to preparing nationals in the use of this knowledge and for extending it.

I believe it is fair to say that most development experts from the 1950s through the early 1970s embraced theories of cultural deficit. A deficit perspective was implicit in Basalla's (1967) seminal work on the spread of modern science to pre scientific societies. He argued that scientists coming from societies with established science (e.g., the USA or UK) in effect colonized science in new locations. Then, given certain necessary cultural, social, and economic developments, modern science would take root and take off in the now formerly pre scientific society. He argued that "resistance to science on the basis of philosophical and religious beliefs must be overcome and replaced by positive encouragement of scientific research. Such resistance... must be eradicated when science seeks a broad base of support at home" (Basalla, 1967, p. 617). Modern science would then bring these pre scientific societies into the modern world. Moreover, many Western development experts in the 1960s believed that science would help bring about a world culture. Dedijer (1962, p. 783) wrote:

> definitions of culture are based on the hypothesis that at present all cultures are evolving in a planned way toward a common world culture... a global civilization. Development then consists in carrying out with the aid of the outside world, but primarily by their own forces, a planned, rapid and simultaneous change of most complexes of their existing cultures in the general direction of the developing world culture.

In the early 1990s, with ethnic and nationalistic rivalries breaking out all over, it is hard to take such ideas seriously, but in 1962 the idea of cultural development was simply consistent with practice in the West. Western educators couched issues concerning Western minority groups, such as African-Americans, in a framework of cultural deficit theory. Moreover, development experts found support for this view in cultural anthropology. Based on Levy-Bruhl's (1926) work, How Natives Think, many anthropologists believed that a great divide separated modern thinking (i.e., the way modern Western intellectuals think) from primitive thinking (i.e., all forms of traditional thinking including those within the West). This viewpoint made education all the more important, because it was education that would transform primitive thinkers into modern thinkers. The underlying assumption is that some cultures promote rational thought while others do not.

In time, the deficit model lost much of its luster, due in no small way to its bald faced ethnocentricity. Nevertheless, the underlying assumption of deficit theory has survived and frequently reappears in the literature of education to day. For example, in the USA researchers periodically imply that conservative religious people have not reached a level of abstract thinking needed to understand science (e.g., Lawson & Weser, 1990). Similarly, it is not uncommon to find research that implies that non-Western, traditional people have not reached a level of abstract thinking needed to understand science (Obekubola & Jegede, 1990). In both cases, whether or not the researchers are

aware of it, the research assumes a deficit model of culture. The traditional culture is deficient because it fosters and sustains modes of thought considered irrational by the researchers. In this perspective, a primary objective of science education is to inculcate scientific thinking as an antidote for irrationalism, that is, traditional thinking.

Rationality is *Not* the Issue

This view has long been held. 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 on thinking, rationality, and cognitive development. 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. In either case the inference is that a person is logical if he or she can successfully complete the assessment tasks. It is well known, however, 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.

These devices require 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. To the contrary, the Swedish psychologist Smedslund (1970) noted that this assumed understanding can only be determined by "observing agreement or disagreement as to (1) what statements are equivalent with the given one, (2) what is implied by the given statement, (3) what is contradicted by the given statement, and (4) what is irrelevant to the given statement" (p. 217). Here lies the difficulty. If the person cannot reason logically, the person will not be able to note equivalence, contradiction, implication, or irrelevance, leaving the researcher unable to determine whether the person 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 person understands 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." In effect, the research assumes what commonsense tells us not to assume. Abiola of Nigeria noted that,

> 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 (1971, p.63).

Indeed, Westerners have long evaluated other cultures by measuring their science and technology against the standards of Western science and technology with predictable results (see Adas, 1989). For education research based on Western instruments to show more positive results, the Non-western subjects would need to have acquired the particular understanding assumed by the Western oriented theory. That this will happen, is the implicit assumption under girding the straight transfer or minimal adaptation of science curricula. Students must conform to a particular understanding to avoid the label of irrationality. For example, in a recent African study the researchers concluded that "rural communities... are apt to explain naturally occurring phenomena through irrational means" (Okebukola & Jegede, 1990, 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.

To summarize my argument to this point, the "above culture" view of science and science education led to notions of cultural deficit based on an assumed rationality gap. The purpose of science education from this perspective is not only the teaching of scientific thinking but also the teaching of rationality by clearing out all traditional irrational thinking. To accomplish this task policy makers employed the transfer and minimal adaptation of foreign science curricula to developing countries.

Cultural Issues and Curricular Adaptation

Science educators have called the decade of the 1960s the "golden era" of North American and European science education curriculum development (Garrison & Bentley, 1990, p. 188). The curriculum developments are called a "revolution in science education" (Prather, 1990, p. 12). 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 through the 1960s toward the transfer of scientific knowledge was little concerned with culture. As one Western educator put it, "a literate nation 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..." Lord (1958, p. 340). Through education, modern science is brought into developing societies where it can displace nonscientific ideas. However, from the time transfer efforts began, expatriate teachers in Third World schools, expatriate teacher education professors preparing nationals to be teachers of science, and many, many nationals with broad cross-cultural experience discovered that transferring a science education curriculum is one thing. Employing it with desired effect is quite another.

Early on, educators 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, for example, and substitute an African cultural bias" (Champagne & Saltman, 1964, p. 1). 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) who conducted science education research in Asia:

> 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. In 1981, based on his extensive research in Papua New Guinea, Maddock called for a more anthropological approach to science education. Yet, six years later, Urevbu (1987) in Africa observed that concerns about cultural sensitivity in science education had yet to be heeded. One finds this observation repeated even today. 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 has meant 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. 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, the American critical theorist Michael 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 in my view unwarranted and counter-productive.

Assumptions about knowledge and reality, values and purpose, people and society that under gird modern science are grounded in Western secularism. This point has been thoroughly addressed by those interested in feminism, culture, and religion. However, curriculum adaptation too often has failed to address underlying assumptions primarily because the policy makers involved have tacitly accepted a cultural deficit and rationality gap viewpoint. 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). Several researchers have had similar findings (e.g., Holmes, 1977; Wilson, 1981). So, what interest is being served?

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. 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 inadvertently and unnecessarily promoted a Western, or otherwise alien, worldview?

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. People do not believe things that do not make sense. They believe precisely because sense is 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 the philosopher Michael Matthews:

> 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... (1992, p. 14).

My view is that there is 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 adverse influence on science education - which is all too common among science educators (e.g., Gallagher & Dawson, 1986).

A Different Set of Questions

Earlier I referred to an African study in which the authors concluded that the rural people taking part in the research were irrational because they used traditional ideas to explain phenomena in nature. 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).

Robin Horton (1967a&b) and Yehuda Elkana (1977) concur. They argue 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. 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 that tacitly suggest that culture is a threat make no attempt to understand how a purportedly superstitious explanation of a phenomena 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.

Science content is science content regardless of culture. I do not hold the strong social constructivist view of science - but not so with its communication. Communicated science, which includes science education, is inculturated. In the jargon of education, there is always a hidden curriculum. This raises two issues which have received little attention. First is the issue of a 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.

1) Must African nations, for example, adapt to science and adapt science to African culture exactly as the West has done?
2) To what extent can science be taught without the cultural dress of the West?
3) To what extent does Western garb inhibit the learning of scientific concepts?
4) What cultural changes are necessary for effective science learning and what changes are unnecessary?

I am of course implying that science education everywhere is too much alike and too Western. How similar is science education around the globe? If you look at equipment and materials, facilities, and teacher preparation then of course there is tremendous variation. But in my view those factors, as important as they are, are none the less not as critical as the strategy and tactics of science education. By **strategy** I mean the policy, goals, and curricula (which includes textbooks) that govern and give form to science education, and dictate the relation science will have with other disciplines. By **tactics** I mean the actions a teacher takes in a science classroom to teach a specific lesson. One tactic is to use traditional knowledge as a way to introduce formal scientific knowledge. My observation is that science education tactics also vary considerably. I find in the literature evidence of great efforts to improve science teaching by taking into account local variations among students, such as language and culture. It is strategy that shows little variation and this is most evident in national policies and in textbooks. The strategy is reflective of what critics call the **mythology of school science** (e.g., Smolicz & Nunan, 1975)

The Culture of School Science

One of my opening comments was that what I have to say here in Durban is also what I say at home (Cobern, in press). There are a number of us in science education who are strongly critical of the form and direction science education has take in the USA and other Western nations. It is scientistic and promotes a culture of school science or worldview that needlessly alienates many students. Figure #4 shows seven categories that compose a worldview (see Cobern, 1991;1993) The descriptors in the center column come from research that critically examined the cultural form in which Western science is embedded, and is employed here only as an example (e.g., Capra, 1982;

Figure #4-Example Descriptors for Worldview Categories

Worldview Categories	Scientistic Descriptors	Alternative Descriptors
The Other or NonSelf	materialistic reductionistic exploitive	holistic social/humanistic aesthetic religious
Classification	natural only	natural social supernatural
Causality	universal mechanistic structure/functional	context bound mystical teleological
Relationship	strict objectivism nonpersonal	subjective personal
Self	dispassionate independent logical	passionate dependent intuitive
Time & Space	abstract formalism	participatory-medium tangible

Merchant, 1989, Skolimowski, 1988; Whatley, 1989). Nevertheless, there is considerable research that suggests this is a relatively accurate description of Western science education. 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. This scientistic worldview is grounded in the three imperatives[3] of modern Western society:

> The Imperative of Naturalism - All phenomena can ultimately and adequately be understood in naturalistic terms.
>
> The Scientistic Imperative - Anything that can be studied, should be studied.
>
> The Technocratic Imperative - Any device that can be made, should be made.

These imperatives serve a single goal: the material well being of people. America's most prestigious scientific organization, the National Academy of Science put it this way:

> In a nation whose people depend on scientific progress for their health, economic gains, and national security, it is of utmost importance that our students understand science as a system of study, so that by

> building on past achievements they can maintain the pace of scientific progress and ensure the continued emergence of results that can benefit mankind (NAS, 1984, p. 6).

This is strategic thinking and when I read UNESCO reports, the *International Journal of Science Education*, or ICASE's *Science Education International*, etc., I see the same strategy over and over again.

About this similarity I would like to make two points. First, I fully agree that science is a necessary component of advanced technological development. Technology is a necessary component of economic development. Necessary but not sufficient. There are many other factors including factors of justice and morality and values that influence all facets of development. Any society, including Western societies, that relies solely on science for the development of technology and economics will be badly disappointed. In other words, however important science and technology are for economic development, they are not in themselves sufficient for economic development. Second, there is more to life than economics. Jesus of Nazareth said it most eloquently: **Man does not live by bread alone**. The economic factor in science is not sufficient to maintain interest in science given the incessant reductionistic pressure of the three imperatives of naturalism, scientism, and technicism which wear away at our views of reality that give meaning to life. The principle problem in American science education today is not lower test scores than the Japanese. It is the loss of meaning. The principle problem in American science education today is the loss of meaning - and economic gain at the cost of meaningful life is a Faustian bargain.

Now let me connect these last two remarks with my earlier comments. Accepting the tight, linear science-technology-economic development (STD) model squeezes out non-scientific ways of knowing and in doing so creates for science (in its scientistic form) a privileged status in society. As this occurs there is increasing pressure for other aspects of culture to conform with scientific thinking. Any areas of resistance come to be viewed as deficiencies because the areas of resistance impede the takeover by scientific rationality. In other words, once the tight linear STD model is accepted, it is very difficult to avoid the charges of cultural deficit and rationality gap. This strategy may in the short run bring some economic growth - but it will do so at great human cost. In my view, the wisest thing any group of science educators can do is to rethink the strategic issues concerning science education. What are we thinking that science can do for us? Have we like the National Academy of Science made a virtual god of science - the one on whom we depend for our well-being? In our strategy for science education, what role have we given to the humanities, the arts, and to religion and morality and values? Or have we accepted the scientistic view that these are all personal and subjective where science is public and objective? One's choice of answers for these questions is critical to the form strategic science education will take and whether there will be authentic alternative constructions of science education.

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[1] I have found that some people object to the use of the adjective "western." Nevertheless I continue to employ the term for good reason. The term dates to the Roman Empire which was composed of western and eastern provinces. In 395 AD the Empire was offically divided into the Latin Western Roman Empire and the Eastern or Byzantine empire. Both empires eventually fell to invaders but the term "west" or "western" survived. At first it represented the former western provinces of the Roman Empire or what later became known as Europe. Today it refers to Europe plus former european colonies which retain strong culture and languange links with Europe, for example, the United States of America or Canada. The use of the term carries with it no inherent value estimation and in no way diminishes the many contributions to Western civilization that have come from Asia, Africa, and other cultures historically understood as non-Western which have been and continue to be considerable. I suspect that those who object to the term do so in the mistaken belief that "west" implies some sort of hegemony.

[2] I am indebted to Skip Hills for the colorful phrasing, "domestic" and "foreign" affairs (see Hills, 1989).

[3] There are many scholars such as Jacques Ellul, Aleksandr Solzhenitsyn, Neil Postman, and Jeremy Rifkin who share this perspective.