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Implications of Socio-Cultural Research Findings for Science Education Reform in Non-Western Developing Countries

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You have the scientific spirit but where is your spirit? The strength of a man's virtue must not be measured by his efforts, but by his ordinary life
- Pascal

Abstract

Many countries in the world, including the less developed ones, acknowledge that socio-economic development will rely for a good part on the rapidity of progress in and adoption of science and technology. As such, school systems have been asked to provide challenging and stimulating science programmes that lead to scientific literacy for all. However, despite the heavy injection of scarce funds and resources to support various science education reform programmes, evaluation studies show disappointingly, that the level of scientific literacy among students and their communities has not risen proportionately to expectations in most developing countries. The programmes generally do not appear to produce telling effects in these societies in the long term. Science educators have, on reflection, begun to look to socio-cultural studies in order to better understand the problems of acquiring scientific literacy in non-Western contexts. These studies collectively find problematic the time-honoured assumption in science education that culturally acquired thought and belief patterns can be readily and simply supplanted by Western scientific rationality leading to 'progress' or to 'development'. This paper explores and articulates the direction school science and science teacher education should take in order to enhance the potential to achieve more global scientific literacy in non-Western developing countries. For there to be meaningful and useful adoption of scientific values and habits, it is argued that there is a need for science education in developing countries to concern itself with the understanding and critical interrogation of the rationality of Western science relative to locally held world views.

Introduction

In this paper I seek to draw attention to the need for science education in developing countries to concern itself with the understanding and critical interrogation of the rationality of Western science relative to locally held world views. John Dewey (1927) once raised a concern with the potential problems related to untrammelled and unreflective use of science and technology by stating:

... the machine age in developing the Great Society had invaded and partially disintegrated the smaller communities of former times without generating a Great Community (p.27).

In the developing countries, science and technology have been embraced as a means to achieving social and economic development. This thrust is evident from the general the goals of science education which by and large mirror of those of the more developed countries in the West (Krugly-Smolska, 2007). Goals of science education increasingly emphasize science education for all citizens so that they may be knowledgeable participants in dealing with and solving problems arising from the increased use of science and technology (Shumba, 1993). Furthermore, greater emphasis is given to the ability to use science and technological knowledge to solve every day problems and to make decisions on societal issues.

All in all, the umbrella goal is the development of scientific and technological literacy. Krugly-Smolska (2007) indicates that the goal of scientific and technological literacy arose “of a need for individual development along with national development in developing countries” (p.479). The goals of scientific and technological literacy are premised on and seek the development of human resources and extending the human capacity to cope with the physical, social and technological environment. However, science and technology are not entirely virtuous as often taken for granted. With this in mind, a higher level of critical reflection on science and technology is desirable, especially in non-Western developing countries where the adoption of a science and technology is seen as a panacea to all developmental challenges.

An assessment of the success of science education

A survey of the literature reviews shows that science curricula in Africa and other developing countries are closely modelled to those in the West (Lewin, 2010; Ogawa, 2007; Ogunniyi, 1988); and that in fact their goals are largely similar in scope (Krugly-Smolka, 2007). In many of the developing countries, examinations are the chief means by which educational achievements are measured. Whether or not they are able to serve as indicators of scientific and technological literacy is subject to debate. However, assessments based on examinations are important if we should be able to make some judgment of the success in science education in the developing countries. One such example is the IEA assessments (Postiethwaite, 1991). A 1984 IEA assessment of junior secondary students showed that the bottom 20% of the students in the developing countries including Nigeria, The Philippines, Zimbabwe, and others were 'scientifically illiterate'. The top 20% consistently scored at bottom of 23 nations surveyed on the literacy measures applied (Postiethwaite, 1991). A recent analysis of examination results in Zimbabwe revealed that of nearly 120 000 candidates taking the compulsory Core Science examinations in 1990, only 20% achieved a pass of GCE grade C or better (Shumba, 1992). A recent survey of science teachers in Zimbabwe shows that they associate science with the production of useful technology and the improvement of human welfare (Shumba, 1995a). They do not see science as parsimonious and tentative, but perceive it in terms of a single-fixed scientific method with a determinate number of procedural steps. The teachers fail to recognize the arbitrary nature of models and classification schemes used in science. They fail to recognize curiosity and human creativity as the fundamental driving force in the advancement of science. Overall, there is greater tendency among the teachers to view science in an authoritarian manner, where it is viewed as an unchanging body of knowledge amassed via the application of determinate scientific methods. They therefore hold a textbook view of science as body of knowledge and immutable laws. Student attitudes towards science, in Zimbabwe at least, seem to wane as students' progress from primary school, to junior secondary, and to high school (Shumba, 1993).

Evidence also exists to suggest that students do not necessarily utilize what they learn in science education in real life. For example, Morris

(1983) observed that in Africa, students go through the audio of memorizing what is necessary to pass tests and examinations after which they return to the security of their traditional beliefs. The African student appears to learn science in ways which contradicts the approaches suggested in science curricula. Odhiambo suggests that the reasons Africans tend to learn by rote is “simply because what is presented to them as science is alien to their ordinary circumstances and life” (p.40). Odhiambo further claims that science teaching has:

... only resulted in his (African) learning facts, procedures and techniques, but has not yet become inbuilt with the spirit of science, with a scientific way of looking at nature and with a scientific manner of approaching new programmes (p.43).

Jahoda (as cited in Swift, 2008), found evidence of persistent traditional superstitious beliefs among Ghanaian undergraduates, “the beliefs existing in a state of cognitive co-existence with Western science education, but emerging more under stress” (p.15). In an interview with teachers who were enrolled for a degree programme in science (Shumba, 1995b), a biology teacher remarked: “*I don't see how science can interfere with my belief, I still have my beliefs... so I still have my beliefs, they are there, science is there too*”. Using the sample of teachers, Shumba (in press), found that science teachers were themselves not strong traditionalists but maintained a fairly traditional posture with regards to aspects of traditional authority, religion, view of nature and social change. They showed a much stronger shift from tradition with regard to sex roles, causality, and problem solving.

Experiences of Westerners who have had some opportunity to work in Africa also suggest that scientific literacy is seen as Western. A decade ago, an American Professor recollected his experience in a Nigerian Teacher's college where he found:

... students who were seeking simple answers to complex scientific phenomena, distressed by the tentative nature of scientific enterprise ... To illustrate the frustration that the level of sure and fixed knowledge can generate, one student made a public appeal that I teach what scientist were sure of! (Shrigley, 2006, p.427).

A recent comparative study of teachers in, Indonesia, Japan, Nigeria, and the Philippines found that irrespective of their non-Western cultural background, the teachers held views distinct from the science they teach. They exhibited a form of collateral thinking whereby “an individual expects or uses both mechanistic and anthropomorphic explanations depending on the context in questions and without exhibiting any sign of cognitive dissonance” (Ogunniyi, Jegede, Ogawa, Yandila & Oladele, 1995). In the sixties, Odhiambo (1980) made a claim that “an African must find a connecting link between the principles of natural science and basic assumptions of his world-view, or he is lost” (p.45). Prophet (2007) working in Botswana observes that there is discontinuity between the common view of reality and the scientific which should concern us. Yakubu (1994) conjectures that “the scientific education given in the developing countries has not succeeded in instilling the scientific spirit in the educated: the indigenous 'common-sense' knowledge is so deeply rooted that it appears difficult to change” (p.344). While this is not to suggest that Africans or people in other developing countries cannot understand or appreciate science and technology; the suggestion is that the spontaneous application of the scientific spirit learnt through Western form of education is lacking. Yakubu (1994) goes on to suggest that:

... there seems there is something which inhibits spontaneous application of scientific ideas to problem situations. The inhibition is very likely to be the deep-seated indigenous and cultural behaviour patterns acquired before western education was received (p.344).

These citations of achievement studies and socio-cultural research raise a possibility that science and technology literacy, the umbrella goal of science education is not being achieved, at least when assessed from the Western point of view. The vast amounts of investment in science education do not seem to find a match in improved standards of living. Yakubu (1994) observes that, in Africa at least, techniques developed way in the past are used “since time immemorial without change” (p.344). This suggests that the inventiveness assumed to characterize a scientific literate person is lacking or not appreciably developed.

Some researchers, like Williams (1994), would have the world believe

that "a major goal of science education must be to dispel notions of magic and teleology as unscientific" (p. 516). Rather than seek to develop literacy, the goal of science becomes that of eradicating belief systems of those that get exposed to it. Cobern (2007) suggests that this view is based on a culture deficit theory where traditional cultures are only seen as different but are tacitly assumed to be less rationale than modern Western culture. Unfortunately this view of the role of science education may be supported, albeit saliently by political leaders in the developing world who may hold problematic assumptions. For example, political headers in the developing countries presuppose that science and technology can and should sow social and economic development much like what happened in the developed world (Cobern, 1989). An example of this is Zimbabwe's Five Year National Development Plan for the period 1991-1995 which stated that "development of science and technology is Zimbabwe's long term and most important strategy for economic and social development" (p.84). Along with this hierarchical assumption of the relationship of science, technology, and development is the absurd logic that the purposes of education in science and technology will lead to the eradication of superstitious beliefs held by many in the developing countries. For example, well placed government officials in Zimbabwe hold this view also prevailing in the developed countries who themselves have assumed that transfer and adoption of Western scientific knowledge and technologies should produce the desired effect of 'modernising' these cultures. Chanakira (1986) once proclaimed that:

... science is one of man's intellectual achievements. It unfolds a picture of the physical world, enables man to extend his knowledge and to exercise control over his environment. In consequence, it is possible for him to reduce poverty, disease and other burdens plus releases him from some of his primitive fears and superstitions (Zimfep, 1986; p. 145; *emphasis added*).

While acknowledging the intellectual nature of the scientific enterprise, a problematic assumption is that exposure to science leads to a rejection of currently held perceptions and views of the world and the implicit assumption that this should necessarily happen. The value judgement implicit in this view is that Westernized scientific rationality is

inherently good, and that people ought to abandon native cultural beliefs to embrace it.

Drori (1993) conducted an analysis which produces innovations which in turn leads to economic development in the less developed countries. A second model, the 'symmetric model' argues that:

science affects national development by transmitting values of development and modernization, while technology offers 'solutions' for the connection between resources and local economic needs. These epistemological considerations define science, technology and development, and social filter processes affect the adoption of such definitions (p. 204; *emphasis added*).

In short, this latter model assumes that inventive activity must occur in the local context rather than mere adoption of knowledge from and finished products. Assuming that the business of science education is to supplant rather than supplement cultural thought and belief patterns demonstrates a serious negation as well as under valuation of cultural thought. And this may be what has been so wrong with science education in the developing non-Western countries.

While arguments about the nature of the world in science materials and science education literature are mostly presented from the vantage point of the scientific world view, the evidence presented suggests that students in developing countries may not have developed a bias towards a scientific interpretation of the world. Two issues emerge from the foregoing. Firstly, scientific and technological literacy as determined by Western standards is not being efficiently achieved with students in developing countries. Secondly, the obvious neglect of the cultural context of teaching and learning in science education has not been helpful to efforts to develop scientific and technological literacy in those countries. Because most science curricula in Africa are modelled on those in the West, their content fail to make a clear distinction between traditional ways of viewing the world and that of science (Cobern, 1993 & 2007; Ogawa, 2007; Ogunniyi, 1988).

Situating science teaching and learning in cultural context

Odhiambo (1968) raised the need for “the recognition that there are certain cultural ideas in the African situation which may well impinge directly on the ease with which an African child can appreciate science” (p.42). More recently, Cobern (1993 & 2007), Ogawa (2007), Ogunniyi (1988), and Swift (2008) raise the issue of the need to relate science more closely to the learner's societal or cultural environment. In his review, Swift (2008) concludes that:

... the bulk of the evidence appears traditional beliefs are an enduring component of indigenous knowledge and thought processes that the science and technology education must work with, in Africa and elsewhere in the 'developing world' (p.16).

Ingle and Turner (2011) find that the way of thinking by pupils from different cultures are different from Western scientific modes of thought. While some, like Odhiambo, make the erroneous assumption that “the irrelevance of cause and effect and the irrelevance of the need for hypotheses for advancing or knowledge of nature is perhaps the most serious gap between the African's world-view and Western science” (p. 45), the issue raised hinges on the potential problems of the intercourse between traditional culture and Western science.

Horton's (1971) analysis refutes this 'irrelevance of cause and effect' assumption of Odhiambo. For example, basing on scientific, anthropological, and philosophical analysis, Horton shows that cognitively, cultures do not differ in terms of their primary theory. Primary theoretical thinking involves the world of common-sense observation and experience. Explanations for observations and experience are based on the personalized idiom whereby social relationships among humans, between humans and spirits, and between humans and objects take precedence. At this level of theoretical development and explanation, the reasoning pattern is largely cosmological and the things on which explanation is based on, for example gods, spirits, and ancestors, are not subject to experimentation. On the other hand, Horton proposes a secondary theory to which societies and cultures eventually develop. In secondary theory,

interpretations or explanations are based on intangible entities and it establishes relationships between ideas and ideas. Relative to primary theory, secondary theory is at a higher level and Western scientific thought has considerably developed upon it. A significant point then is that, in the primary theoretical system which would be predominant in traditional culture, causality is based on human volition (i.e. the personalized and subjective idiom) rather than in that of the material world.

Horton (1971) suggests an important difference between traditional thinking and science as that “in traditional cultures there is no developed awareness of alternatives to the established body of theoretical beliefs, whereas in scientifically oriented cultures, such an awareness is highly developed” (p. 230). This makes traditional cultures to be 'closed' while the latter are 'open'. The closed predicaments can be found in attitudes pertaining to the prediction events, to cause and effect, towards experiment, towards confession of ignorance, towards coincidence, chance and probability, attitudes to problem solving, and attitudes towards time. These attitudes are amply summarized by Ingle and Turner (2011, p. 364). Horton (1971) gives a more detailed analysis and critique of these and other attitudes. Shumba (1995b) provides a summary of the cultural values and norms in Zimbabwe.

- 1) Attitudes towards the prediction of events: Although both the traditionalist and the scientist are concerned with the prediction of events, the former will find excuses for each successive failure while the latter would modify the theory. The traditionalist also fails to see the incorrectness of his or her theory or knowledge.
- 2) Attitudes towards cause and effect: The traditionalist tends to converging causal sequencing where, for example, an illness can be linked to multiple causes, i.e., when action is taken to deal with one cause and the action fails, another cause is sought which is supposedly a complicating factor. Regardless of the number of failures the theory is retained and not discarded.
- 3) Attitudes towards experiment: Traditional thinkers tend to wait for events to come along and show the validity of a theory while scientific thinkers would put the theory to the test of

experiment.

- 4) Attitudes towards confession of ignorance: Traditional thinkers are reluctant to confess ignorance about the answer to any questions including natural calamities such as floods, disease or droughts.
- 5) Attitudes towards coincidence, chance and probability. Explanations for any calamity are always sought and the idea of chance, probability or coincidence is simply not well developed.
- 6) Attitudes towards time: Traditionalists tend to see things as having been better in the past.
- 7) Attitudes to problem solving: Traditional thinkers tend to accept solutions to problems invented in the past instead of inventing solutions to present problems. Solutions have to be remembered. Solutions to problems tend to be transmitted from generation to generation.

While Yakubu (1994) observes that the gap between the aims and values of science and technology and indigenous culture is not very wide since both are engaged in explaining and controlling the environment, he observes a clear gap exists in that science uses a systematic experimental technique which is "completely absent in indigenous thought and practice" (p. 344) and thus techniques developed way in the past are used "since time immemorial without change" (p. 344). Further, he notes that while indigenous thought and practice is rational and pragmatic, it has what Skorupski (1976) termed building 'blocks of falsifiability' which makes it non-tentative and unaware of its limitations. Yakubu (1994) says this is problematic since:
... even though people have been well educated in science, when they are faced with problems and the discarding of old ideas and the construction of new and better ones, they find it difficult to give the old ones up. Sometimes the scientific solutions are put aside and the indigenous ideas adhered to. The ease with which this is sometimes done can be worrying: reasons are always found to maintain the status quo (p. 343).

Teaching and learning science non-western countries, particularly those in Africa, should therefore seek to bring both scientific way of

thinking and traditional rationality into some form of interaction hopefully leading to some meaningful conflation. Certainly the nature and nurture of the interactions should not simply be ignored or disregarded, as mostly the case in the past and currently.

Science education, curriculum and pedagogy

The importance of culture vis-a-vis learning is articulated by Saljao (1991) who posits that it is no longer tenable to assume that perception, attention, memory, reasoning and other similar processes are unaffected by culture. In short, cognitive phenomena are related to culture. Saljao says culture is “what allows us to perceive the world as meaningful and coherent and at the same time it operates as a constraint on our understandings and activities” (p.180). Culture in this regard serves as a filter through which we perceive the world and render it intelligible. Saljao also stresses the point that “human experiences are inescapably cultural in nature, learning and growth *take place* within cultural boundaries” (p. 184). Stanley and Brickhouse (1994) find problematic the universalistic assumption of science education and suggest that we need to develop a multicultural perspective on scientific knowledge. The universalistic assumption supposes that science is science, and *science* is the same throughout the world (Ingle & Turner, 2011). Thus Western science content and methods can be transferred to the Third World without consideration of the cultural milieu of the pupils. Concomitant with this assumption is the erroneous viewpoint of “Western science embodied in school curricula usurp traditional beliefs systems and attempt to change practice” (Ingle & Turner, 2011, p.360).

The problem currently analyzed is that science education cannot afford to pretend to be accultural since it produces effect on the societal system which it is introduced. For example, when a society is traditional and its belief system is founded on mythology, such a society is expected to adjust and accommodate the 'stress' from the interaction with science. Ingle and Turner (2011) suggest three ways by which the adjustment might occur, viz. (a) social disintegration due to the overpowering effect of the stress, (b) acceptance of the challenge in an idealized form and thus it will be less powerful than it can be, and (c) assimilation and coexistence of old and new ideas. The latter, assimilation, is a thinking process whereby new ideas are pondered, compared to existing beliefs.

and find a place among existing beliefs. In other words, there is productive confrontation between the new and the old. This can happen in revolutionary fashion where displacement occurs without assimilation or in an evolutionary fashion where the new is accommodated with assimilation and integration.

Science education in developing countries has sadly been revolutionary rather than evolutionary and thus its impact has been unfortunately limited. Ogawa (2007) and Ogunniyi (1988) propose that science education should be relativised so that it can be seen within the context of students' indigenous culture. Ogunniyi (1988) suggested that for the scientific world view to succeed in traditional societies, "the aim should be geared towards accommodation rather than assimilation ... the aim of science education I am proposing here should not be to supplant or denigrate a traditional culture but to help people meet modern challenges" (p.8).

Another point concerns pedagogy. Lewin (2010) observes that pedagogical approaches do not always travel well across cultures but unfortunately the science education community has not been fast in recognizing and/ or accepting this. He makes the following worthy observation:

The contradictions which may be involved in teachers moving towards teaching methods that stress enquiry, unfettered questioning, challenges to traditional beliefs, and the lodging of authority in the physical world of experiment and hypothesis testing, in communities where none of these things is the normal conduct of affairs, require forethought. If the purpose of teaching science is partly to hasten the development of a *gessellsschaft* grounded in the rationality of scientific thinking, it may require an approach that not simply confront and dismiss beliefs that are widely shared (p. 17).

Jegede and Okebukola (2007) posit what they call the conceptual eco-cultural paradigm in which the growth and development of an individual's perception of knowledge is made to draw from the eco-cultural environment in which the learner lives and operates. They suggest that the science curriculum should be modelled along the

African thought system which the learner brings to the classroom and uses as the conceptual framework for constructing personal ideas about phenomena. The curriculum should base and utilize the African view of nature and the traditional cosmology, a point substantiated by Cobern (2007), Ogawa (2007), Ogunniyi (1988), and numerous others. Among objectives Jegede and Okebukola (2007) propose is the need for teaching values of the typical African feelings in relation to and in the practice of (science and) technology as a human enterprise (p. 45). They recommend that the curriculum and instruction for learners of non-Western society “must begin with and reflect on the world views they already possess” (p.46).

This is especially appropriate if we note the findings of Prophet's (2007) research in Botswana. Prophet finds that the values instilled in the home are in fundamental disagreement with the spirit of inquiry; and critical attitude is actively discouraged and this is probably reflected in the passive, accepting atmosphere observed in the classroom. Learning is unreflective and by rote; the teachers see themselves as authority figures whose word is not questioned, and most pupils simply want clear instructions of what is expected of them and clear standards against which they must perform (p. 20).

Rakow and Bermudez (1993) report on evidence from research which showed that Mexican American families emphasize conformity and solidarity and as a result individuals in that culture tend to respond to “adult and family expectations rather than to self-directed goals. Consequently, their focus of control is external as they pursue the opinion of others to validate their own experiences” (p. 672). Kay (1975) provides an interesting case study of Kenya where he observes that educational changes must compete for allegiance with long standing traditions which must be taken into account in curricula development and implementation. For example, he notes an attempt to introduce a child centred curriculum there. The pupils, especially from rural areas, had been socialized to learn by listening to storytelling, by direct observation but not participation, and were socialized to work cooperatively. At an early age, the children were taught values and attitudes related to collectivism and submission which were the antithesis of “spontaneity, self-reliance and individualism being

and created in schools' (p. 188). The authority of age and respect of older persons was a well ingrained virtue and personal decision making "does not appear to be a part of the cultural baggage" (p.189). Teachers themselves tasked with implementing the 'progressive' curriculum' carried the same values and failed to put themselves on equal footing with their pupils and therefore remained stern authorities in their classrooms. As a nation Kenya "is very intent upon preserving its traditional heritage and culture" (p. 190); similarly, Cobern (2007) notes that "the advancement of science and science education often competes with national interest in maintaining the integrity of traditional culture" (p. 6).

Kay (1978) makes an observation which could be true today in many African countries, that while "both pupils and teachers are of a culture which undergoing significant changes, persists in cherishing certain traditions and actions" the curriculum design process "has not even recognized these types of problems, let alone found effective ways of dealing with them" (p. 190). Prophet (2007) concludes that a new science education should be a synthesis of the "esteem for the richness of African cultural values and humanistic traditions combined with the knowledge, values and attitudes needed to understand and control the world of today" (p.21).

The Ogawa (2007) model, later extended by Ogunniyi (1988), raises "greatest concerns, considering the aims of science education is how we can bring science as a culture into their traditional or fundamental culture... to compare the traditional and the scientific view of man and nature and ways of thinking, and to clarify similarities and differences between them" (p. 115). Ogawa (2007) proposes that science education should make students aware of:

- 1) their traditional culture
- 2) characteristics of science as culture which has different view of man and nature, a different way of thinking
- 3) examples of conflicts between scientific and traditional ways of thinking in everyday life, and
- 4) training in decision making related to science

Obviously one would expect that science should supplement rather than replace their cultural background. Swift (2008) cites Mazrui who finds that some African academics are experiencing cultural isolation because they “have allowed Western science and technology to replace rather than supplement their cultural background” (p. 3). Overall, it appears that Western science is transferring to developing countries without its essence and consequently does little to improve the overall human capacity. Science educators in the developing countries are challenged to take seriously the issue of cultural thought vis-avis scientific thinking. A serious re-evaluation of traditional culture in science education is required. Ogawa (2007) suggests that science should be viewed in a cultural context and relativised and that science as a culture should be seen within the context of students' traditional culture. Science educators should take heed of these suggestions if they are to avoid presenting science dogmatically. They must assist teachers understand the kinds of interactions that occur when science encounters local cultures; otherwise, there is possibility of uncritical acceptance or even rejection.

Scientific vies of science and the assumption of virtuosity

Another problem confounding efforts to develop scientific and technological literacy in developing countries is the lack of critical reflection and analysis of the nature of science itself. There is docile acceptance of the value of science and technology especially as they are construed to have a link to 'progress and development' and therefore virtuous. This attitude and belief is subjectively strengthened by the unnecessary dichotomy: Choose traditional values or choose Westernized values as practised in the past (and currently) in science education. There is always the attendant danger of replacing traditional world views with the new dogma of unquestioned science.

Skolomowski (1974) criticizes the mechanistic and materialistic conceptions of progress at the expense of “other concepts of progress, of a metaphysical and religious variety” (p. 53) as an illusion. He characterizes the Western concept of progress in five ways:

- 1) Pragmatic: Progress mainly preoccupied with material gains and practical improvements of the immediate future.
- 2) Empiricist: World is viewed as made up of physical parts

interacting mechanically.

- 3) Scientist: Laws of physical science viewed as tools by means of which we manipulate the physical universe.
- 4) Exploitive: Conquering, controlling, and exploiting nonchalantly and ruthlessly of natural resources and balances in the ecosystem.
- 5) Elitist: Progress benefits a few at the expense of the many and at the expense of natural resources belonging to all.

Similarly, Ogunniyi (1988) suggests that while the achievements of science are for all to see, assumptions such as above make the appreciation of science and technology in developing countries a little more problematic.

In his analysis, Skolomowski (1974) concludes that “the progress of science and progress in general are two different things” (p. 60) and that “the metaphysics of progress is based on an exploitive and parasitic form of philosophy. Progress has been a cover-up for Western man's follies in manipulating the external world (p. 77). While we have accrued benefits and advantages such as better medical care, better living standards, better and more efficient communication services, and extended our life expectancy, the Western form of progress has disrupted ways of life of other cultures without significant gains in Western standards of living, depleted natural resources, caused ecological imbalances, and created ways of life in which “we have disengaged the individual from the variety of interactions with nature and other people in which he was engaging in former ways of life” (p. 78). The question for science educators is whether they can afford to have the dichotomy: Choose Westernized values or traditional values which for a long time have been the obvious choice of colonists and cultural imperialists. The stance by science teachers in Zimbabwe is a counter to this point; they acknowledge the value of science but admittedly have not abandoned their traditional beliefs and values in order to embrace it. In fact, in the research by Shumba (1995), Zimbabwean science teachers are themselves not strong traditionalists but maintained a fairly traditional posture with regards to aspects of traditional authority, religion, view of nature, and social change. They showed a much stronger shift from tradition with regard to sex roles, causality, and problem solving.

From my point of view, this balance of tradition and change is laudable. Loss of tradition means the loss of cultural cohesion because scientific thinking, for all its power to explain physical phenomena, is incapable of providing a unifying view of life. While science and technological advancements are appreciated, science fails as a unifying metaphysic ((William & Cobern, personal communication, 6 April 1995). Further, science and technology helped to create a plethora of modern ailments that can be traced to anxiety, stress, pointlessness, and pollution. Science and technology cannot guarantee social cohesion like tradition does; people influenced by Western values are disconnected from one another and from their environment; and social alienation is a serious even fatalistic problem. On the same issues, Michael O'Loughlin (personal communication, 6 April 1995) provides a useful critique noting that indigenous culture is resilient and conservative in order to maintain itself. On the other hand, Western science, economics and international aid are often imperialistic. Not all of Western science is virtuous as commonly noted about the role of pharmaceutical and petrochemical multinationals in environmental despoliation and deforestation in South America, displacement of native agricultural practices and dietary habits, etc.

What passes for science education is dogmatic. It is another ideology with all of its own baggage so that while the public face of science and the scientific method is that of objectivity and rationality, it is deeply ideologically bound and can be deployed as a means of oppression and mystification (Birch, 1988; Boulding, 1970; Kelly, Carisen & Cunningham, 1993; Hodson, 1993; Skolimowski, 1974). O'Loughlin suggests that the issue for science education should be "less of an attempt to displace one mind-set and replace it with a more 'scientific' but rather to bring them both into conversation in some critical ways" (personal communication, 6 April 1995). This raises a possibility that traditional cultures are not monolithic and totally closed relative to scientific rationality, rather the resistance to the tenets of the Westernized world view embodied in science could perhaps suggest that traditional culture may be open to other possibilities such as conceptualizing emancipator, environmentally and socially conscious scientific enquiry.

Boulding (1970) suggested that in some sense the scientific subculture could serve to disorganise society rather than move it towards progress. Some of the virtues are in stark contradiction to values held within traditional cultures, for example, veracity and curiosity. As he says folk proverbs show that curiosity killed the cat. On the other hand “the scientific subculture, and the technological ‘superculture’ it has produced, are not and probably cannot be a complete culture” (Boulding, 1970, p. 17). Boulding then pauses is that:

What we have to think of, therefore, is much more of a symbiosis between the scientific subculture and the other subcultures with which it interacts, rather than any sort of conquest of the other cultures by a kind of universal church or culture of science (p. 17).

It is our problem as science educators to create this symbiosis and “the impact of the various subcultures on each other, particularly in regard to their value systems” (Boulding, 1970, p. 17). Appleyard, Marty, Boorstin and Anees (1993) also express scepticism on the virtuous nature of science by stating:

Science is not an innocent commodity which can be employed as a convenience by people wishing to partake only of the West's material power. Rather it is spiritually corrosive, burning away ancient authority and traditions. Science, which pretends to be all-knowing, cannot coexist with alternative belief systems (p. 52).

They further critique science and the scientific method for being simply “inadequate for coping with the soul of man, which required explanations and guides for living they cannot offer” (p. 53). Appleyard and his colleagues also feel that an entirely scientific society cannot work, “though full of rationality and discovery, it fails to shed any light on the distressing phrase ‘the reason to live’” (p. 55).

Cobern (1993) depicts science as a powerful cultural force which threatens, needlessly, the integrity of a traditional culture. Therefore, we find that science and technology are criticized on moral and ethical grounds. Mundangepfupfu (1989) criticizes science partly because it “cannot inform us about the reality of beliefs about morals, values, art,

magic, etc.” (p.49). Ziman (1971) suggested that “moral responsibility is therefore an issue that cannot be decided by scientific investigation” (p. 113). Science and scientists have been accused of not thinking “of people, of pain, of freedom, and of beauty” (p. 116) and hence Ziman concludes that “teaching responsibility in science is also teaching science” (p. 117). A Horton (1971) suggested, the greater concern of people in the developing world is people and their relationships, and the personalized idiom with which they confront the world should be a concern in this regard.

Kelly, et al, (1993) criticize Robert K. Merton's conception of the norms of science which were largely seen to be valid during their time. These Mertonian norms of science are:

- 1) Universalism: This assumes that scientific knowledge is independent of the personal, social, cultural, and national attributes of the scientist.
- 2) Communism: This assumes knowledge should be shared openly within the scientific community.
- 3) Disinterestedness: This assumes that scientists have desire to extend the domain of human knowledge without personal interest such as personal aggrandizement.
- 4) Organized scepticism: This expects scientists to use only empirically established facts in scientific decision making and to suspend judgement until the evidence *found*.

The Mertonian norms present science as dependent upon value free observation (i.e. separation of theory and prior knowledge and observation) in inductivist approach experimentation. The knowledge thus gained is construed to be absolute and beyond reproach. Mundangepfupfu (1988) criticizes science construed as the only valid form of knowledge:

... the notion of reality derived from those views of nature is limited because the realm of application of scientific beliefs is reduced to the observable in the physical world. Science operates only within a notion of reality restricted to the physical universe and, therefore, cannot explain any other reality or tell us if there is or not such a reality (p.49).

In Zimbabwe, at least, some science teachers in fact are aware of the limitation of science and the falsity of pretending that its bounds of knowing are limitless (Shumba, 1995b). One of my interviewees, a biology teacher said:

It would also be good for science education to remove the myths surrounding the instruction of science by explaining things to the learners that science has got certain limits. There are some spiritual powers, these powers could be godly or they could be sinister, and science is concerned with tangibles or things that can be investigated but this does not rule out the existence of spiritual forces. People can go into a mountain and disappear; there are spiritual forces that are sinister which sort of disturb their minds, confuse them, that exist. It's something that cannot be solved by science; they (spiritual forces) are above science, they transcend science (Shumba, 1995b, p. 276).

Stanley and Brickhouse (1994) suggest that a Universalist conception of science is problematic because it creates the absurd impression that scientists can know 'the truth' about the world and second, "it rationalizes the destruction of knowledge systems deemed inferior by Western standards" (p. 392). Echoing this sentiment, Hodson (1993) suggests a multicultural perspective in science education which thrives on comparative analysis of science in other cultures. For example, he cites evidence (Smolicz & Nunan, 1975; Sardat, 1989) that in the Western mode of the curriculum, the image of a scientist is that one of the self-assured, technologically powerful manipulator and controller yet Islamic scientists stress the need for humility, respect for what is studied, and recognition of the limitations of science. Among the Maori there is appropriate respect and recognition of the spirituality of land forms such as sea mountains, and forests. In Africa, maintaining harmonious relationships between people and the natural world is vital. Understanding the cultures of people where science has been introduced is surely part of the business of science education.

Birch (1988) provides an interesting critique of the modern world view driven by science and technology as mechanistic and materialistic. It is "deficient as a total world view and has left us with a dilemma about ethics and values and purposes" (p. 12) and "our most difficult

problems (e.g., hunger, poverty, war) involves values and purposes” (Birch, 1988, p. 19). Birch identifies eight negative consequences of the untrammelled application and belief in the ability of science and technology to resolve problems in the modern world. He provides a substantially sacrosanct summary of the major criticism of the classical-empiricist notions of science, namely:

- 1) The fallacy of misplaced concreteness or the fallacy of reification or the naturalistic fallacy which '*thingfies*' natural objects and supposes that the human is a machine and thus negates the reality that human being experiences and feels and wonders. Separates the natural from the human and supposes that human 'thought' can be extrapolated and derived from 'what is' in the non-human world.
- 2) The generic fallacy: Supposes that the origin of something or ideas settles the question of its falsehood or its truth.
- 3) The prosaic fallacy: Refusal to attribute feelings to things that feel and failing to acknowledge that the natural world is a feeling world.
- 4) The fallacy of posteriori reasoning: Assuming that the physical environment was made or pre-ordained to fit life and a rejection of the notion of chance and accident. Living things and humans live in this environment without need for self-determination or adaptation because the original design is just right.
- 5) The fallacy of objectivity: The notion that science is objective in the sense that subjectivity does not enter into scientific analysis; rejection of multiple explanations and insensitivity to values and failure to bestow values on facts.
- 6) The dogmatic fallacy: Rejection of competing or alternative systems of thought or view points.
- 7) The fallacy of the perfect dictionary: Assuming that single words and phrases express accurately the fundamental ideas on what we know; not recognizing the role of imagination and criticism in preference to catchwords and phrases.
- 8) The bricks-to-babel fallacy of knowledge: A belief in the accumulation of facts and division of knowledge created by experts and entrusting experts to guide us into truth and right action; separation of knowledge domains into disciplines rather than demonstrate their unity.

Post-modern views of science and the connection with culture

Science education is now seeking to get informed by perspectives from both the philosophy and sociology of science. Science is now understood to be a socially constituted enterprise “shaped at many levels by human values, beliefs, and commitments” (Kelly et al., 1993). Contrary to Mertonian norms there exists counter norms that suggest that the scientific enterprise is value laden. According to Longino (cited by Kelly et al., 1993), two value types permeate science. The constitutive values are the science specific values to which serve to demarcate what constitutes acceptable scientific practice and/or method while the contextual values are the personal, social, and cultural commitments inherent in any environment (p. 213). The implications of these notions are that:

- 1) scientific knowledge should be understood as tentative and contingent upon the social conditions that govern its construction and taught accordingly
- 2) science education should establish parameters to make students aware of the role of social consensus in the construction of knowledge
- 3) socio-cultural values influence the process, content and application of scientific knowledge
- 4) science is not the only cognitive authority for decision making
- 5) learning science does not necessarily make citizens good public decision makers

The relativist views concerning science education are reasonably grounded in philosophical studies and analysis of the nature of science. In addition to these philosophical and social studies of science refuting the strict objectivism and classical realism of positivist thought (Cobern, 1993), a very insightful critique is given by Matthews (2010) who support and rationalize a social constructivist view of learning. According to this view, learning is an interpretive process, greatly influenced by prior knowledge and experience (Posner & Strike, 2007). In the learning process, the learner constructs knowledge, not simply receive it passively (Cobern, 1993). Posner and Strike (2007) contrast conceptual change with the classical empiricist philosophy of Locke

and Hume which uses the metaphor of *tabula rasa* for mind and learning and thus neglects the role of prior knowledge and experience in learning new material. Cobern (2007) views learning as involving the negotiation and interpretation, both processes of which are influenced by prior knowledge and experience. The key point is that prior knowledge and experience obtains from cultural experience and socialization. For these reasons it is pertinent, as Cobern (2007) intimates;

... 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 social-cultural milieu of students (p.11).

Reflective and contextualized science education

It seems, then, that such sensitivity and sentiments for science education has relevance to attaining the goal of critical scientific and technological literacy. In his doctoral dissertation, Mundangepfupfu (1988) argues for the need to deal with the problem of teaching science to students who might have a magico-traditional conception of the world and castigates historical (and current) practice which accepts the antithesis between scientific and traditional beliefs "without considering the conceptual differences of world views" (p.3). The persistence in science education of notions such as those expressed by the likes of Williams (1994), who says that "a major goal of science education must be to dispel notions of magic and teleology as unscientific" (p. 516), is surely detrimental and indeed disfigures any attempts to present a truthful, holistic, and meaningful rendition of whole human experience. Reform is critically needed to alter science material and science education literature which are mostly presented from the vantage point of the scientific world view because, as Mundangepfupfu notes, "this bias towards a scientific interpretation of the world is arbitrary and construes (reality) as scientific reality" and yet, as a way of viewing the world, scientific beliefs have strengths and weaknesses like other world-views (p.3). Mundangepfupfu posits that if science teaching in Africa is to be successful:

... must involve a wider conception of legitimate knowledge than the present narrow conception of knowledge as scientific knowledge. ...the question of what and how to teach science to students who adhere to magico-traditional beliefs can then be approached through the argument that science is a way of knowing one aspect of reality and that other world-views present alternative ways of knowing the world (p.4).

This rationale is clearly supported in the literature (Cobern, 1993; Ogawa, 2007; Ogunniyi, 1988). Clearly, it is no longer the business of science education to make students reject their traditional beliefs and thinking and accept scientific beliefs and knowledge unquestioningly. Mundangepfupfu rejects the time honoured assumption saying “there is nothing to say that the eradication of other beliefs will lead to a better understanding of science. Furthermore, science cannot account for all phenomena in nature and it is unclear why it is better to have one world-view rather than many” (p. 86). On a similar point, Stanley and Brickhouse (1994) find that the modern science framework is quite powerful when applied in certain situations but “Western scientific frameworks cannot provide a vantage point beyond other frameworks whereby we could judge, once and for all, what we can know” (p. 395). They therefore see advantage in multiple perspectives rather than the current monological-science-is-best perspective concluding that “human interpretation aimed at the realization of new knowledge requires the dialogue of multiple perspectives (frameworks)” (p. 395).

Stanley and Brickhouse (1994) suggest that students need to become competent in scientific discourse:

... they also need to understand that this is only one particular way, among many, of thinking about the natural world. Put another way, we believe that teaching a universalistic conception of science is miseducative and could potentially lead to repeating the negative consequences of a Universalist view. ...they can also learn that the form of contemporary science is not universal, inevitable, or unchangeable. This kind of understanding is needed to encourage critical thinking ... (p. 396).

On the same issue, Hodson (1994) argues that:

... the overarching goal of Science for All program should be critical scientific and technological literacy, and to achieve this goal it is necessary both to personalize learning and to politicize science education. Thus my views are rooted very firmly in the notion of critical thinking and social-political action on matters that relate to scientific, technological, and environmental issues (p. 521).

Conclusion

In this regard it becomes essential to dispel the dogma of unquestioned science through critical interrogation of Western science relative to indigenous thought and belief of adopting cultures. It is not the business of science education in developing countries or indeed elsewhere to bring about loss of tradition. Culture is not an obstacle to overcome as Williams (1994) assumes; it is not an obstacle to science or other forms of thought, belief or knowledge. There is no evidence that loss of tradition is necessary condition for the adoption of scientific new points. Scientific progress is in itself not all virtuous and neither is it inherently good (Shumba, in press). It is crucial for cultural issues to be included in the curriculum. Both cultural issues and science should be subjected to critical discourse with the hope that science and tradition can be brought into conflation. Wright (2007) rejects the superficial study of science, attached to an authoritarian pedagogy which conveys “that there are probabilities rather than certainties, degrees of confidence rather than absolute laws” (p. 374), which may have the positive spill over effect into other areas of experience.

Developments elsewhere show earnest attempts to understand the conceptual nature of traditional thought and belief in creating innovative approaches that seek to influence students' understanding of science and to inculcate in them the scientific world view. However, these well intentioned efforts will come to naught if reflective inquiry and analysis targeting science and culture does not occur. What is needed is perhaps more of what Matthews (2010) proposes, that “science education should be an education *about* science as well as in science” (p. 12).

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