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CRITICALLY INTERROGATING THE RATIONALITY OF WESTERN SCIENCE *VIS-À-VIS* SCIENTIFIC LITERACY IN NON-WESTERN DEVELOPING COUNTRIES

OVERSON SHUMBA

Department of Teacher Education, University of Zimbabwe

Abstract

Science and technology have often been yoked to social and economic development of many countries in the world, including the less developed ones. In these the heavy injection of scarce resources to support science education programmes, has, disappointingly, raised only a little the level of scientific literacy among students and their communities; science education programmes do not appear to produce long-lasting scientific and technological literacy. This article articulates the problems of acquiring scientific literacy in non-Western contexts. Socio-cultural studies collectively find that a people's locally and culturally acquired thought and belief system cannot be simply supplanted by Western scientific rationality leading to 'progress', neither is it necessarily desirable for that to happen. For there to be meaningful adoption of scientific values and habits, there is a need for science education in developing countries to concern itself with the critical interrogation of the rationality of Western science relative to locally held world views.

DOMINANCE AND NAIVE ACCEPTANCE OF THE RATIONALITY OF SCIENCE

THIS ARTICLE IS an attempt to portray 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. Anne Griffin (1997, 3) talks about a vision of human and social progress critically linked to science and further, of rationality as 'centrally construed as the development and application of scientific principles'. However, she finds that this rationality has become instrumental rationality for its neglect of self-reflectiveness and for its setting aside of value considerations, and is therefore problematic. Birch (1988, 12) sees the modern world view driven by science and technology as mechanistic, materialistic, and 'deficient as a total world view and has left us with a dilemma about ethics and values and purposes'. Appleyard (1993, 23, cited in Midgley, 1997, 78) describes science's 'corrosive and restless refusal to coexist' with other cultural thoughts and values with which it competes. Unfortunately, not appreciating the rationality of science and especially its differences with that of the adopting culture,

less developed countries have been gullible in accepting science and its assumed role in development and modernisation. For example, Midgley (1997, 71) cites the words of Pandit Nehru (1960) when he addressed the Indian National Institute of Science: 'It is science alone that can solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people'.

Science alone and its rationality is thus assumed to be good for all countries seeking to develop or to modernise, and such countries should abandon tradition and custom (and assumably the rationality on which they are based). Harvey Williams (1994, 516) even makes the problematic assumption that 'a major goal of science education must be to dispel notions of magic and teleology as unscientific'. Cobern (1994) suggests that this view is based on a culture deficit theory where traditional cultures are not only seen as different but are tacitly assumed to be less rationale than modern Western culture. Unfortunately, unwittingly accepting this culture deficit theory, many assume that transfer and adoption of Western scientific knowledge and technologies should produce the desired effect of 'modernising' these cultures. The value judgement implicit in this view is that Westernised scientific rationality is inherently good, and that people ought to abandon native cultural beliefs to embrace it. 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 under-valuation of local knowledge and thought may be what has been so wrong with science education in the developing non-Western countries so far. In fact, a survey of the literature reveals how closely science curricula in Africa and other developing countries are modelled closely on those in the West (Lewin, 1990; Ogawa, 1986; Ogunniyi, 1988). This unfortunately is not seen as problematic and no meaningful attempts to contextualise the curricula are made. For example, arguments about the nature of the world in science materials and literature on science education are mostly presented from the vantage point of the scientific world view; the only rationality presented is that of science without making a clear distinction between it and traditional ways of viewing the world (Cobern, 1993; 1994; Ogawa, 1986; Ogunniyi, 1988). As a consequence, many students in developing countries have not developed a bias towards a scientific interpretation of the world.

Against such assumptions Swift (1992, 16) concludes that the bulk of the evidence appears to be that traditional beliefs (and the rationality on which they are premised) 'are an enduring component of indigenous knowledge and thought processes that the science and technology educator must work with, in Africa and elsewhere in the developing

world'. Yakubu (1994, 344) 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'.

Overall, the development of science and technological literacy in developing countries is problematic; it is complicated by the adoption and modelling of the curriculum on the erroneous grounds of the culture deficit model. This article portrays 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. In an attempt to clarify the basis for this thesis, we first survey the science education literature relating to achievement and attainment of scientific literacy in some less developed countries. Second, a detailed review of socio-cultural studies and their implications for science education is given. The literature has been taken from many different contexts: this is not to suggest that societies are the same, rather the nature of the broad problems dealt with are comparable and in some cases even similar.

SUCCESS OF SCIENCE EDUCATION IN THE DEVELOPING COUNTRIES

The International Association for the Evaluation of Educational Achievement (IEA) assessments pointed to the poor performance in science of students in developing countries when compared to their counterparts in the developed countries; the 1984 assessment of junior secondary students showed that the bottom 20% of students in the developing countries including Nigeria, the Philippines, Zimbabwe, and others were 'scientifically illiterate'; they consistently scored at the bottom of 23 nations surveyed on the literacy measures applied (Postlethwaite, 1991). In Zimbabwe, 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, 28). Surveys of science teachers in Zimbabwe (Shumba, 1995a) and in Nigeria (Cobern, 1989) showed that they associated science with the production of useful technology and the improvement of human welfare: they failed to recognise curiosity and human creativity as the fundamental driving force in the advancement of science. Teachers in the Zimbabwean sample viewed science in an authoritarian manner as an unchanging body of knowledge amassed via the application of a determinate scientific method: they had a textbook view of science as a body of knowledge and immutable laws. In another study, primary school, junior secondary, and high school students valued science from only a materialistic standpoint in so far as it led to the production of useful technology (Shumba, 1993).

Evidence also exists to suggest that African students do not necessarily utilise what they learn in science education in real-life (Morris, 1983; Yakubu, 1994, 344). Morris (1983, 23) observes that students go through the ordeal of memorising what is necessary to pass tests and examinations after which they return to the security of their traditional beliefs. Odhiambo (1968, 40) found that African students learned science in ways which contradicted approaches suggested in science curricula 'simply because what is presented to them as science is so alien to their ordinary circumstances and life'. Consequently, science teaching has 'only resulted in his (Africans) learning facts, procedures and techniques, but he has not yet become imbued with the spirit of science, with a scientific way of looking at nature, and with a scientific manner of approaching new problems' (Odhiambo, 1968, 43). Jahoda, as cited in Swift (1992, 15), found evidence of persistence of 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'. Recently, I interviewed 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 same sample of teachers, Shumba (1999, in press), found that the 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. An American professor found that Nigerian science students were distressed by the tentative nature of the scientific enterprise; 'there was a tendency to embrace, even tongue-in-cheek, information having a superstitious base, but at least a definite answer, in preference to wrestling with several scientific alternatives' (Shrigley, 1983, 427). A comparative study of teachers in Botswana, 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, and they exhibited a form of collateral thinking whereby 'an individual accepts or uses both mechanistic and anthropomorphic explanations depending on the context in question and without exhibiting any sign of cognitive dissonance' (Ogunniyi, *et al*, 1995, 817). In the sixties, Odhiambo (1968, 45) made a claim that 'an African must find a connecting link between the principles of natural science and the basic assumptions of his world-view, or he is lost'. Prophet (1990) working in Botswana observed discontinuity between the common view of reality and the scientific view among students.

These findings together do not suggest that Africans or people in other developing countries cannot understand or appreciate science and technology. Rather the suggestion is that the spontaneous application of the scientific spirit learnt through Western forms of education is lacking (Yakubu, 1994, 344). In this regard, Yakubu conjectured that 'there seems *something which inhibits the 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'. The points arising from the review so far raise a possibility that science and technology literacy, the umbrella goal of science education, is not being achieved in non-Western developing countries, particularly those in Africa. The explanation of the limited success of science education seems to lie in the difference between indigenous thought and belief and world view promoted in science. Odhiambo (1968, 42) 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'. More recently, Cobern (1993; 1994), Ogawa (1986), Ogunniyi (1988), and Swift (1992) raised the issue of the need to relate science more closely to the learner's societal or cultural environment. The assumption of diametric opposition of traditional rationality and scientific rationality, premised on the culture deficit theory (Cobern, 1994) should be challenged.

TRADITIONAL RATIONALITY COMPARED TO WESTERN SCIENTIFIC RATIONALITY

The fact that traditional rationality and scientific rationality are different but not necessarily diametrically opposed has been explored for decades (Bourdillon, 1990; Horton, 1971; Odhiambo, 1968; Yakubu, 1994). These differences, often quite subtle, should be the subject of analysis and critical discourse in science education. For example, Odhiambo (1968, 45) claims 'the irrelevance of cause and effect and the irrelevance of the need for hypotheses for advancing our knowledge of nature is perhaps the most serious gap between the African's world-view and Western science'. The issue raised hinges on the potential problems of the intercourse between traditional culture and Western science; between traditional rationality and scientific rationality. Horton (1971) argued that cognitively, cultures do not differ in terms of their primary theory which involves the world of common-sense observation and experience. At this level of theoretical development and explanation, the reasoning pattern is largely cosmological and the things on which explanation is based, for example gods, spirits, and ancestors, are not subject to experimentation. Horton (1982) emphasising continuity between African

traditional thinking and Western modernism suggests that primary theory entities and processes are more directly observed or experienced and do not differ from culture to culture but their causal vision is limited. 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. Relative to primary theory, secondary theory is at a higher level and Western scientific thought has considerably developed to it. Secondary theory being more ideational is more 'hidden' but is directly dependent on analogies of everyday experiences of primary theory for causal explanations. Horton (1982, 232) conjectures that 'explanations couched in terms of secondary theory are only complete when their implications for the world as described *by primary theory* have been set out'. Secondary theory appears to be 'enslaved' to primary theory without replacing it; without distorting Horton's thinking, is it possible that the modernity, in the developing countries, supposed to be represented by science (secondary theory) can build on traditional thought (primary theory) without replacing it?

A significant point is that, in the primary theoretical system which would be predominant in a traditional culture, causality is based on human volition (i.e., the personalised and subjective idiom) rather than in that of the material world. In his modified thesis, Horton (1982, 224) dropped the closed-open predicament assumption and suggested that traditional thinking

> despite its conservatism, such thinking has an essentially 'open' character. Second, it tends to produce and sustain a single over-arching theoretical framework rather than a multiplicity of such frameworks.

However, this change in traditional thinking does not arise on the basis of criticism, rather, it seeks assimilation and continuity; it does not lend as much weight to critical self-analysis and self-refutation; it does not actively or persistently seek to refute or falsify existing knowledge. On the other hand, Bourdillon (1990, 226) observes that:

> the ideal of science to criticise its ideas, and the acceptance that its theories may be wrong is in striking contrast to religious systems that dismiss alternative views, or at least dismiss an attempt to critically assess the symptom itself; *but we cannot make too much of this distinction because people in even the most simple societies are usually open to new ideas*. What is largely true is that in traditionally religious systems, knowledge is assumed to come largely from the past and wisdom to lie with elders, whereas in the scientific system, the past is constantly superseded and has no authority of its own (*emphasis added*).

Horton (1982, 239) sees this as cognitive traditionalism where knowledge or the accepted theory has been handed down from the

'ancients' and where all members of the community 'share a single overarching framework of secondary theoretical assumptions, and carry out intellectual innovation within that framework', i.e., are engaged in a 'consesual' mode of theorising. On the other hand, he sees modernism in terms of a progressivistic and dynamic concept of knowledge where a body of theory is in process of gradual change and improvement and where rival school of thinkers engage in competitive modes of theorising, promoting mutually incompatible frameworks of secondary theoretical assumptions (p. 239). There is a willingness to try out radical new theoretical ideas but any cognitive defects in these new ideas is monitored critically in terms of consistency and empirical adequacy. The difference between traditional thinking and scientific thinking thus lies on the level of theory on which they are predominantly engaging; traditional thinking does not go much beyond primary theoretical analysis while scientific thinking functions at both the primary and secondary theory levels and deliberately seeks to develop the latter. While Horton's argumentation does not equate traditional thought to Western science, the implication is that the traditional African thought is not completely devoid of scientific notions, and of rationality; in any case 'rational thinking is the *sine qua non* in the survival of any society' (Emereole, 1998, 68). Emereole (1998) found that illiterate Batswana adults held both valid and culturally influenced scientific notions about common practices and phenomena. The gap between the aims and values of science and technology and indigenous culture is therefore not as wide as it has been made to be since both cultures are engaged in explaining and controlling the environment. Only a clear gap exists in that science uses a systematic experimental technique which is absent in indigenous thought and practice (Yakubu, 1994, 344). Yakubu notes that while indigenous thought and practice is rational and pragmatic, it has in-built 'blocks of falsifiability' which makes it non-tentative and unaware of its limitations. Yakubu (1994, 343) 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'.

This apparent resilience to change is not unique to traditional communities or cultures; in fact scientists and their professional communities are, relatively speaking, quite conservative. For example, Kuhn (1970) described the development of science as happening through periods of normal science when there is among the science community commitment and consensus on conceptual, theoretical, instrumental, and methodological fundamentals and hence continuation of a particular research tradition. However, scientific revolutions occur when too much evidence (or anomalies) has accumulated against some fundamental

assumptions and a new paradigm emerges. Bourdillon (1990, 227) notes that radical revolutions entail casting off old frames of reference and developing new ways of thinking but 'elderly scientists try to maintain the old framework'. Kuhn (1970, 24) finds that normal science is itself conservative and that 'no part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are not seen at all. Nor do scientists normally aim to invent new theories, and they are often intolerant of those invented by others" and further, 'in science . . . novelty emerges only with difficulty, manifested with resistance, against a background provided by expectation. Initially, only the anticipated and usual are experienced even under circumstances where anomaly is later to be observed' (Kuhn, 1970, 64). Activities of normal science do not aim to produce major novelties; relatively speaking, the activities in traditional communities remain stable similar to the periods of normal science. The gist of the matter is whether or not the differences and/or similarities in the rationality of traditional and scientific thinking should be the subject of critical analysis and reflection in science education. Science education, particularly in Africa, should seek to bring both the scientific way of thinking and traditional rationality into meaningful conflation. This should happen deliberately, consciously, and reflectively; a contextualised science curriculum and pedagogy is needed.

CONTEXTUALISED SCIENCE CURRICULUM AND PEDAGOGY

The importance of culture *vis-à-vis* learning is articulated by Saljao (1991, 180) who finds that cognitive phenomena are related to culture; it is not tenable to assume that perception, attention, memory, reasoning and other similar processes are unaffected by 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 (1991, 184) also makes the point that 'human experiences are inescapably cultural in nature, learning and growth take place within cultural boundaries'. Stanley and Brickhouse (1994) and Turner and Ingle (1981) find problematic the universalistic assumption of science education which supposes that science is the same throughout the world and thus its content and methods can be transferred to Third World countries without consideration of their cultural milieu. Concomitant with this universalist assumption is the questionable viewpoint of 'Western science embodied in school curricula usurps traditional belief systems and attempts to change practice' (Turner and Ingle, 1981, 360). The problem currently analysed is that science education cannot afford to pretend to be accultural

since it produces effects on the societal system in 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' through either social disintegration due to the overpowering effect of the stress, or through acceptance of the challenge in an idealised form which will be less powerful than it can be, or through assimilation and coexistence of old and new ideas. The latter, assimilation, is an evolutionary thinking process whereby new ideas are pondered, compared to existing beliefs, and find a place among existing beliefs. Ogunniyi (1988, 8) suggested that for the scientific world view to succeed in traditional societies, the aim of science education 'should not be to supplant or denigrate a traditional culture but to help people meet modern challenges'. On pedagogy, Lewin (1990, 17) concludes that 'if the purpose of teaching science is partly to hasten the development of a *gesselisschaft* grounded in the rationality of scientific thinking, it may require an approach that not simply confronts and dismisses beliefs that are widely shared'. It is therefore imperative to deal with contradictions introduced in teachers moving towards teaching methods that stress enquiry and the challenging of traditional beliefs in communities where none of these things is the normal conduct of affairs. For example, Prophet's (1990) study in Botswana found that values instilled in the home were in fundamental disagreement with the spirit of inquiry and critical questioning to be developed in science education; he finds that 'an innovative 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' (Prophet, 1990, 20). Rakow and Bermudez (1993, 672) indicate that traditional families emphasise conformity and solidarity resulting in individuals in that culture tending to respond to 'adult and family expectations rather than to self-directed goals. Consequently, their locus of control is external as they pursue the opinion of others to validate their own experiences'.

Kay (1975) provided an interesting case study of Kenya where he observed that educational changes competed for allegiance with long-standing traditions. For example, he notes an attempt to introduce a child-centred curriculum there. The Kenyan pupils especially from rural areas had been socialised to learn by listening to story telling, by direct observation but not participation, and were socialised to work co-operatively. 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 advocated in schools' (Kay, 1975, 188). The authority of age and respect of older persons was a well ingrained virtue and personal decision making were not a part of the cultural baggage. 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 in many African countries, Kenya was very intent upon preserving its traditional heritage and culture. Similarly, Cobern (1994, 6) notes that 'the advancement of science and science education often competes with national interest in maintaining the integrity of traditional culture'.

These observations have direct implications for curriculum and pedagogy where both pupils and teachers are of a culture which, undergoing significant changes, persists in cherishing certain traditions and actions. Unfortunately, as Kay (1975) noted, the curriculum design process does not recognise these types of problems, let alone find effective ways of dealing with them. There is an increasing number of critical voices calling for the science curriculum to be modelled through the African thought system (Cobern, 1994; Ogawa, 1986; Ogunniyi, 1988). Jegede and Okebukola (1991, 45) recommend that the curriculum and instruction for learners of non-Western society must begin with, and reflect, the world views they already possess. Prophet (1990, 21) envisages a new science education which is 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'. Ogawa (1986) proposes that science education should make students aware of their traditional culture as distinct from science as culture which has a different view of man and nature and a different way of thinking. Further, it should exemplify conflicts between scientific and traditional ways of thinking in everyday life. Failing to take seriously the issue of cultural thought *vis-à-vis* scientific thinking, Western science is transferring to developing countries without its essence and consequently does little to improve the overall human capacity there. Ogawa (1986, 115) noted that the greatest concern in 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'. A serious re-valuation of traditional culture in science education and its influence in acquiring scientific literacy is required. Otherwise, the possibility of uncritical acceptance or even rejection poses a serious challenge; scientism and the assumption of virtuosity should be dispelled.

DISPELLING SCIENTISM AND THE ASSUMPTION OF VIRTUOSITY

Efforts to develop scientific and technological literacy in developing countries also flounders through 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 are virtuous. In many developing countries, this attitude and belief is subjectively strengthened by the unnecessary dichotomy: choose traditional values or choose Westernised 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, 53) criticised the mechanistic, materialistic, exploitive, and elitist conceptions of progress at the expense of 'other concepts of progress, of a metaphysical and religious variety' as an illusion. Similarly, Ogunniyi (1988) suggests that while the achievements of science are for all to see, progress linked only to the rationality and empiricism of science makes the appreciation of science and technology in developing countries a little more problematic. In his analysis, Skolomowski (1974, 60) concludes that 'the progress of science and progress in general are two different things' 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, and better and more efficient communication services, the Western form of progress has disrupted ways of life of other cultures without significant gains in Western standards of living, depleted natural resources, and caused ecological imbalances; it has 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' (Skolomowski, 1974, 78). The question for science educators is whether they can afford to have the dichotomy: choose Westernised values or traditional values which for a long time has been the obvious choice of colonists and cultural imperialists. In many developing countries science teachers acknowledge the value of science but admittedly they have not abandoned their traditional beliefs and values in order to embrace it (see Ogunniyi, *et al*, 1995; Shumba, 1995b; 1999, in press). If anything the teachers demonstrate a balance of traditional values and scientific thinking.

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 W. 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 and perhaps even a 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. Not all of Western science is virtuous as commonly noted about environmental despoliation and deforestation, displacement of native agricultural practices and dietary habits, etc. 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" one but rather to bring them both into conversation in some critical ways'. 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 Westernised world view embodied in science could perhaps suggest that traditional culture may be open to other possibilities such as conceptualising emancipatory, environmentally and socially conscious scientific inquiry.

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 "super-culture" it has produced, is not and probably cannot be a complete culture' (Boulding, 1970, 17). What Boulding then proposes 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 (*Ibid*).

It is our problem as science educators to create this symbiosis and to assess 'the impact of the various subcultures on each other, particularly in regard to their value systems' (Boulding, *Ibid*). Appleyard *et al* (1993, 52) also express scepticism on the virtuous nature of science by stating that

> 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.

They further critique science and the scientific method for being simply inadequate for coping with the soul of man, which requires explanations and guides for living they cannot offer. 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). Mundangepfupfu (1988, 49) criticises science because it 'cannot inform us about the reality of beliefs about morals, values, art, magic, etc'., and therefore portrays science as one of many limited and fallible forms of knowledge by stating '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' .

GENDER, EQUITY, AND ANTIPATHY TOWARDS SCIENCE

This article would be incomplete without also looking at the problem of gender, equity, and antipathy towards science *vis-a-vis* the girl child. In particular the masculine image embodied in the scientific world-view and socialisation practices in the traditional culture should not be left as unproblematic. As explained in earlier sections, philosophers, historians and sociologists have raised questions concerning science as being objective, rational, individualistic, unemotional, and value free, and for depicting the scientific enterprise as a male domain. This image of science partially arises consequent of its development predominantly from a male Eurocentric perspective (Roychoudhury, Tippins, and Nichols, 1995, 898). This portrayal of science carries with it both gender and ethnic biases and stereotypes. Roychoudhury *et al* note that '(scientific) knowledge is socially situated, and in a gender-stratified society, differentiated male and female roles will render different perspectives for the generation of knowledge' (p. 898). Drawing on tenets of feminist standpoint theory, they suggest that examples and applications used in science teaching are masculine and classroom interactions sanction male dominance, and at the deeper epistemological level, the nature of the knowledge that is accepted as scientific embodies a masculine world-view. In their critique, they find that in science, 'women's experiences have been neglected as the progenitor of knowledge claims, making science partial, incomplete, and weak' (*Ibid*). This partial percept of science often is carried through in science education dominated usually by males. Women are often under-represented in the print and pictures in curricular materials such as books, workbooks, and audio visual materials; however, these resources consume as much as 90% of a student's learning time: this carries the implicit message that in society and in science women are less important. The linguistic bias asserts the terms *he* and *man* as representative of all people (Bullock, 1997, 1022).

In Zimbabwe, Marira (1991) found that some textbooks used in primary schools carried sexist language which favoured boys over girls 81% of

the time. The third person was translated to 'he' about 42.6% of the time compared to the third person being translated to 'she' 2.1% of the time. Women were more likely in the texts to be presented in domestic chores such as cooking and sewing while males were shown to be in technical occupations such as construction. In science, this masculine image can lead girls to have less confidence than boys in their ability to succeed in science, even if they perform as well as boys (Meece and Jones, 1996, 401). Additionally, curricular materials together with the masculine and positive image of science they carry reinforce and perpetuate sex-role and other cultural stereotypes for both girls and boys. For example, in Zimbabwe, gender biases and stereotypes are deeply ingrained in the traditional culture arising from this emphasis on sex role differentiation (Aschwanden, 1982; Bourdillon, 1987; Bozongwana, 1983). Dorsey (1992, 373) notes that in the patriarchal society of Zimbabwe, 'the system operates to enhance the position of men and relegates women to a subordinate position where it is more difficult for them to compete on equal terms'. Shumba (1997) traced the under-representation of women in education and training and in science and technology related careers to the predominant culture which conserves vast areas of traditionalism with regard to gender socialisation. Gordon (1995) found that secondary school girls gender typed occupations in a way that mirrored societal expectations and beliefs about the role of women. They perceived professions such as nurse, secretary or typist, dress maker, and library service as being 'better' for women, and they perceived school subjects like science, building studies and metalwork as masculine, difficult, and unsuitable for females.

Sex role differentiation and gender typing also appears to influence girls to prefer certain sciences and not others. For example, in one study quoted in Weinburgh's (1995) meta-analysis, girls had more positive attitudes to biological sciences than to the physical sciences; on the other hand girls who take up the physical sciences perform as well as their male counterparts (Shumba, 1997). In Africa, early childhood training may make females feel that the biological sciences are more acceptable areas of interest to them. For example, in Nigeria, (Jegede and Okebukola, 1992, 643) found that in traditional socialisation boys are allowed to undertake activities which can promote better perception of science as a career opportunity; 'they are allowed to climb trees, set traps, go fishing, dismantle mechanical objects, probe valleys, caves and hills, chase butterflies, build models, and explore the environment' while girls, on the other hand, are prevented from engaging in risk-prone activities and exploring the environment in the same vigorous manner.

In feminist theory, the different social experiences of men and women give them different ways of looking at life and interpreting events, and

therefore different standpoints. In addition to attitudes, girls and women may have a different way of learning rooted in their role in culture (Roychoudhury, *et al.*, 1995, 897). The mechanistic and scientistic portrayal of the nature of science as objective, individualistic, unemotional, and value free makes the feeling of personal bonding with the subject and context unacceptable; yet it is thought that females prefer this personal bonding and exhibit emotional and connected ways of knowing that arise out of their real life experiences within society (Roychoudhury, *et al.*, 1995, 899). Relational values such as cooperation, working with people, and helping others are imminent in society and are more appealing to women in science. Women's learning preferences and styles would seem to be better supported in a culture providing a supportive interactive environment; such an environment favours co-operation and collaboration rather than the detached, unemotional, masculine, competitive, and individualistic environment often promoted in science. The relational values are promoted vigorously in most traditional cultures, and therefore such cultures have something to offer in terms of frameworks for developing appropriate pedagogical cultures and environments, not only for gender sensitivity but for equity in general. Kuiper (1998, 21) asserts that 'science is not a culturally independent phenomena; it comes with a way of viewing the world and with certain values attributed to the kind of knowledge it deals with'. The explicit values and the implicit images of the nature of science should be subject to critical discourse *vis-a-vis* socialisation practices in the home and in schools or else science education will persistently fail to cater fully for pupils from different cultures and of different sexes and ethnicity. What is needed, therefore, is a search for curriculum and pedagogy that are culture sensitive; this search will not succeed without the critical interrogation of the basic rationality of science, which should include also feminist voices and critiques.

MULTI-CULTURAL SCIENCE EDUCATION

Stanley and Brickhouse (1994, 392) 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 rationalises the destruction of knowledge systems deemed inferior by Western standards'. Echoing this sentiment, Hodson (1993; 1994) suggests for science education a multi-cultural perspective that thrives on comparative analysis of science in various cultures. For example, he cites evidence (Smolicz and Nunan, 1975; Sardar, 1989) that in the Western model of the curriculum, the image of a scientist is one of the self-assured, technologically powerful manipulator and controller, while 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. In fact, dealing with the issue of culture is supported if one looks to the social constructivist theory of learning (Mathews, 1992). According to this theory, learning is an interpretative process, greatly influenced by prior knowledge and experience (Posner and Strike, 1982). In the learning process, the learner constructs knowledge, not simply receives it passively (Cobern, 1993). Posner and Strike (1982) emphasise that conceptual change, i.e., learning, depends on currently existing prior knowledge and experience in learning new material. Cobern (1994) views learning as involving negotiation and interpretation, both processes that are influenced by prior knowledge and experience. The key point, in our argument, is that prior knowledge and experience obtain from cultural experience and socialisation and therefore for effective learning of science and its values to occur, culturally acquired experiences and knowledge cannot (or rather should not) be ignored. For these reasons it is pertinent

> 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 (Cobern, 1994, 11).

It seems, then, that such sensitivity and sentiments for science education have relevance to attaining the goal of critical scientific and technological literacy. Mundangepfupfu (1988, 3) castigates historical (and current) practice which accepts the antithesis between scientific and traditional beliefs 'without considering the conceptual differences of world views' when it comes to teaching science to students who might have a magico-traditional conception of the world. The persistence in science education of notions such as those expressed by the likes of Williams (1994, 516), who says that 'a major goal of science education must be to dispel notions of magic and teleology as unscientific', is surely detrimental and indeed disfigures any attempts to present a truthful, holistic, and meaningful rendition of the whole human experience. Reform is critically needed to alter science materials and science education literature that are mostly presented from the vantage point of the scientific world-view. As Mundangepfupfu (1988, 3) 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. Mundangepfupfu (1988, 4) posits that if science teaching in Africa is to be successful, it must involve a wider conception of legitimate knowledge whereby science is a way of knowing one aspect of reality and that other world-views present alternative ways of knowing the world. This rationale is clearly supported in the literature (Cobern, 1993; Ogawa, 1986; Ogunniyi, 1988).

Clearly, it is not the business of science education to make students reject their traditional beliefs and thinking and accept scientific beliefs and knowledge unquestioningly. Mundangepfupfu (1988, 86) rejects this 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'. On a similar point, Stanley and Brickhouse (1994, 395) 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'. They therefore see advantage in multiple perspectives rather than the current monological-science-is-best perspective concluding that 'human interpretation aimed at the realisation of new knowledge requires the dialogue of multiple perspectives (frameworks)' (p. 395). Stanley and Brickhouse (1994, 396) 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.

On the same issue, Hodson (1994, 521), argues that the overarching goal of Science for All should be *critical* scientific and technological literacy, and to achieve this goal it is necessary both to *personalise* learning and to *politicise* science education and 'thus my views are rooted very firmly in the notion of critical thinking and socio-political action on matters that relate to scientific, technological, and environmental issues'.

CONCLUSION

This article has argued the limitations of the scientific world-view depicted in adopted curricula as the only world-view. It sought to dispel the dogma

of unquestioned science by demonstrating the need for 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 a necessary condition for the adoption of scientific views and values. Aspects of thinking, valuing and believing arising from one's indigenous culture and arising in the pursuit and study of science should be subjected to critical discourse with the hope that science and tradition can be brought into conflation. Wright (1982, 374) rejects the 'superficial study of science, attached to an authoritarian pedagogy' in favour of a more 'open' form of science and pedagogy which conveys that 'there are probabilities rather than certainties, degrees of confidence rather than absolute laws' which may have the positive spill-over effect into other areas of experience. In some countries there are 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, and comparison of science and culture does not deliberately occur: for equity and for posterity, critical discourse should include also feminist voices and standpoints.

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