2008

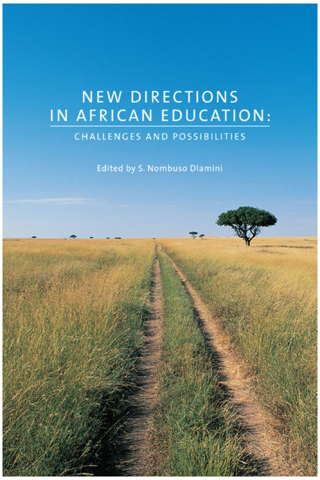
New directions in African education: challenges and possibilities

University of Calgary Press

"New directions in African education: challenges and possibilities". Edited by S. Nombuso Dlamini.Series: Africa, missing voices series 4, University of Calgary Press, Calgary, Alberta, 2008.

http://hdl.handle.net/1880/48649

book



NEW DIRECTIONS IN AFRICAN EDUCATION: CHALLENGES AND POSSIBILITIES

Edited by S. Nombuso Dlamini

ISBN 978-1-55238-564-7

Acknowledgement: *We acknowledge the wording around open access used by Australian publisher,* **re.press**, *and thank them for giving us permission to adapt their wording to our policy* http://www.re-press.org/content/view/17/33/

2

SOME ISSUES OF SCIENCE EDUCATION IN AFRICA

Wanja Gitari

ABSTRACT

This chapter explores issues that dominate science education debate in Africa today. Two key focal points of the chapter are gender inequity, which results in an under-representation of girls and women in science, and the efficacy of content learned in schools, which is highlighted by the inability of science graduates to readily transfer the knowledge they gained in school to everyday problem-solving situations. The chapter illustrates that these problems may be moderated through the adaptation of various teaching approaches. Five approaches are targeted as beneficial in addressing gender inequalities and knowledge adaptation: (1) Education with Production, (2) constructivist teaching, (3) Science, Technology, Society and the Environment, (4) anti-racist science teaching, and (5) co-operative learning. The chapter highlights the need for policy-makers, educational institutions, and teachers to recognize that they must work together to make transformative education a reality in

African nations. It concludes by affirming the need for transformative education for students by teachers who are prepared with sufficient resources to engage their pupils.

INTRODUCTION

Until the 1980s, the primary concerns of science educators and policy-makers had been the availability of textbooks, the use of more realistic, practical, and experimental work, and the use of more appropriate teaching methods. Clearly, educators were grappling with ways to improve how students acquire scientific knowledge, which included increasing the number of textbooks and making certain that experiments were part of science learning. Emphasis was, therefore, laid on the experimental method as a means for teaching scientific inquiry with the hope that students would think like scientists. Yet, the science-centred orientation did not enable science education to achieve its goal of applying science knowledge to everyday situations, and educators continued to question its effectiveness.

There are two key pedagogical issues currently dominating the science education debate in Africa: (1) the underachievement and under-representation of girls and women in science; (2) the efficacy of the content knowledge learned in school, that is, the inability of the majority of science graduates to transfer the science knowledge they gained in school to everyday problem-solving situations. Educators suggest that some of these problems might be minimized through the adaptation of various teaching approaches. This chapter offers insight into the science pedagogy debate in Africa, through a discussion of the two issues. The chapter then highlights five teaching approaches as possible and desirable learning models: (1) Education with Production (EwP), (2) constructivist teaching, (3) Science, Technology, Society and the Environment (STSE), (4) anti-racist science teaching, and (5) co-operative learning.

These approaches are discussed in the context of three pedagogical orientations to science curricula: science-centred, learner-centred, and society-centred. All three orientations may find expression in a single curriculum, although in most cases curricula tend to lean towards one of them. These orientations are important to understand because many of their elements have been adopted by the five teaching approaches itemized above.

In the science-centred orientation, emphasis is on content knowledge, structure of science, or scientific inquiry. Curricula are geared towards the acquisition of scientific facts, procedures, and processes. Textbooks, laboratory, and laboratory materials are very important learning tools and most of the teaching proceeds through didactic methods of instruction.

In the learner-centred orientation, focus is on learning activities that enhance the development of the student's affective, normative, and psychomotor domains, and an attempt is made to integrate science learning with the child's environment. For example, in a lesson on plants a child learns about different plants and their functions by visiting surroundings where plants are found. There is a belief in the ability of the child to construct knowledge from experience. Examples of teaching approaches that are adopted for learner-centred orientation are discovery learning and the constructivist method of learning.

In a society-centred orientation, the curriculum is planned so as to enable school science to benefit society in more defined ways. For instance, the likelihood that the study of science will result in a scientifically literate society is considered when planning curriculum activities. The relevance of scientific knowledge for the development of industry and technology and environmental solutions is also considered. Also, there is a tendency to plan science curriculum along lines that follow science careers presently available for science graduates. Resulting from its focus on the needs of society, this approach tends to link education with production and to be concerned with knowledge discontinuity and elements of gender and contextualized knowledge. Two teaching approaches that incorporate the society-centred orientation are Education with Production (EwP) and Science, Technology, Society and the Environment (STSE).

GENDER INEQUITIES

In the late 1960s, the feminist movement laid the foundations for problematizing women's status in science and technology (Rose, 1994). Researchers have since grappled with different aspects of this issue. For example, sociological, feminist, and psychological paradigms have enabled researchers to gain knowledge into social and psychological factors that contribute to the underachievement and under-representation of women in science and technology. Gilligan (1982) reported that many women tend to avoid both science- and technology-related professions that take too much time away from important family roles and relationships. A consideration of personal effect, together with the development of interpersonal relations, is therefore central to the way in which women appropriate knowledge (Hodson, 2003).

Globally, there is a persistent concern for girls' and women's underachievement and under-representation in science (UNESCO-CAMSTE, 2001; Jenkins, 2003; Sjøberg, 1998; UNESCO, 2004). The causes are broad and varied, often embedded in the socio-historical, economic, and political facets of society. Feminist scholarship has contributed insightful theories and frameworks in the study of women's participation (or lack thereof) in the sciences, in European and North American contexts. Although the implications of this body of literature in an African context are not clear, in general, research has pinpointed problematic areas in science education globally. Factors such as sex-stereotyping in textbooks, teaching methods, teacher's attitudes, inequality in the breadth of subject matter (Kinyanjui, 1985; 1993), and bias in teaching and structure of science curricula are considered as possible impediments to women's participation (Woodhouse & Ndongko, 1993; Harding & Apea, 1990). Some of these impediments can be narrowed down to particular aspects of the science curricula. Women's participation, for instance, is restricted through the use of gender stereotyping in the curricula, gender streaming by subject, and limited recruiting of girls into scientific and technical education (Kinyanjui, 1985).

Another factor that has been identified as key to gender inequity is the school structure. In Cameroon, for instance, Woodhouse and Ndongko (1993) found that covert and systematic forms of discrimination are hard to identify, therefore, more difficult to overcome. According to these authors, on average, educators are able to identify overt factors that determine achievement in science, for example, the preferential questioning and encouragement of boys by teachers. Covert factors such as the organization of the school system in a way that enables boys to learn science better (in a well-equipped-all-boys' school) than girls (in a poorly equipped girls' school) are not easily identifiable. Arguably, covert factors are largely responsible for the current status of girls and women in science.

A 1991 UNICEF study reported that, despite quantitative expansion, which resulted in massive enrolment of girls at all levels of schooling in Africa in the 1980s and 1990s, less than 20 per cent of girls chose science as a career (UNICEF, 1991). Kinyanjui (1985) argued that it is not only questions of how many enrol in science but also what kind of science is offered. Others have argued that science learning that over-emphasizes the acquisition of scientific knowledge as facts and "truth" may not appeal to girls. Baker and Leary (1995) identified an aspect of school science that may work against girls as the lack of a genuine connection with the socio-cultural and environmental contexts in which people live. They observed that, when girls are presented with a science that is more socially and environmentally centred, they tend to participate more.

Within the African context, a genuine connection that enhances a personal identification with science requires an appreciation and use of the "fundamental scientific and technological principles, theories, and concepts of the indigenous practices within African society" (Jegede 1994, p. 126). Science education in Africa has neglected this aspect of science teaching – even as the goals of teaching science in Africa have shifted throughout the years to ensure that science serves people better (Ogunniyi, 2005).

CONTEXTUALIZED SCIENTIFIC KNOWLEDGE

Traditionally, the teaching of science emphasized concepts, ideas, and theories that were of interest and importance to scientists but not to the learner (Hodson, 1988). This tradition can be traced to a hypothetico-deductive model of doing science where the natural world is believed to have an objective existence. According to this belief it is possible to know reality as it exists in the natural world through orderly and repeatable procedures like planned experiments. By employing objective methods, like experimental procedures, scientists acquire facts about natural phenomena.[1] The knowledge so acquired is said to be unbiased and universal, and separate from the background (social, political, economic) of the scientist. The extent to which the questions asked or the methods used are culturally determined is not an issue. The philosophy behind this view of science is commonly referred to as "natural humanism" or "positivism."

Natural humanism is transmitted to students when scientific knowledge is depicted as facts, and when observation in experimental procedure is depicted as an accurate means of fact acquisition. The message the learner receives is that what one requires in order to discover the laws of the universe are experimental procedures and careful observations. Given this approach to science, the role of the learner is a passive one because all the necessary tools, namely experimental procedures and rules of observation, are provided.

To counter this view of science and to engage students in an active learning of science, educators are advocating a "constructivist" way of teaching that is based on Kuhn's (1970) concept of "consensus building" and reconceptualist ideologies (Eisner, 1992). The constructivist view argues that the nature of science is constituted of symbols, is socially negotiated, has an empirical basis, and does not rely solely on observable and verifiable facts. Accordingly, constructivists argue that to view scientific knowledge as culturally neutral, value-free, absolute, and unproblematic is to promote a particular bias and a particular set of values (Hodson, 2003).

In following the constructivist view of science, for the purposes of science education in Africa, one would want to know to what extent the science taught in schools is culturally determined and what teaching approaches would be appropriate in exposing the distortions and inaccuracies promoted by conventional science curricula (Nyamnjoh, 2004). Within Western science studies, the History, Philosophy, and Sociology (HPS) of science is a branch of science studies that addresses the questions of how, why, and in what contexts scientific knowledge is constructed. In school curriculum, HPS is taught through Science, Technology, Society, and the Environment (STSE) courses. Other teaching approaches that are used to expose the distortions and inaccuracies of science promoted by conventional science curricula are anti-racist and anti-sexist science teaching (Atwater, 1996; Keller, 1989; Vance, 1987). The application of these teaching approaches in Africa remains questionable, since, according to Nyamnjoh (2004) their efficacy in the attainment of science education goals in Africa in the context of specific learner characteristics, teacher preparedness, curricula structures, general education policies, and the social economic context of learning in the African region has not been systematically studied. Moreover, most African countries are currently focusing on resolving major educational issues in funding, policy, and curricula restructuring and do not have the resources to invest in systematic studies on pedagogy. Issues of learner characteristics and teacher preparedness that are so central to effective teaching and learning may have to wait until the major problems of education have been resolved. The current situation on pedagogy is captured in part by an observation by Ogunniyi (2005): "The conventionally trained science teachers at our higher educational institutions have been so schooled in the scientific mode of inquiry that they can hardly perceive the enormous difficulties that learners from indigenous cultures encounter in their classrooms" (p. 3).

The essence of a science curriculum should never be taken for granted. Fensham (1988) argues that, since definitions of science evolve within the context of developed countries, their usefulness to science discourses in developing countries should be questioned. Also, imported courses make unrealistic assumptions about the general milieu of the school, which includes prevailing world views, learner characteristics, school equipment, teacher training, and out-of-school environments (Sjøberg, 1998). Such importation also inhibits more appropriate local development of ideas and innovations (Reiss, 1993). The historical transferability of curriculum from developed to developing countries was partly based on the belief in the "universal" and absolute aspects of science. However, this belief fell apart as science educators in Africa became aware that curricula adapted from developed countries did not help to achieve most of the science education goals set out by the African ministries of education (see Urevbu, 1984).

In Africa, other concerns for contextualized scientific knowledge that have taken centre stage are the extent to which alternative viewpoints influence the learning and teaching of science (Ogunniyi et al., 1995; Ogunniyi, 2005); the use of aspects of African[2] indigenous science that are of value to science education (Yakubu, 1994); and the inclusion of the scientific achievements of African scientists in school curriculum (Murfin, 1994). It is of paramount importance to rid the curriculum of views of universalism, imperialism, and racism (Rose, 1994) ingrained within the colonizing medium and whose purpose was to "sanitize and civilize" the "primitive" African cultures (Jegede, 1994). The force behind the civilizing mission was the belief that African educational thought was organized around a supernatural mode of thought. Consequently, defining the African world view as one based on the supernatural led to the erroneous belief that Africa did not contribute to modern science. However, new evidence that has traced the growth of modern science to ancient Egypt, then occupied by black Africans, has rendered these earlier claims false and racially motivated (Ogunniyi, 2005; Sertima, 1983). Similar views of women's contributions to science are refuted by current feminist scholarship.

The Western notion that there is a distinction between the supernatural and the natural is a highly contested one in the study of African thought. Horton (1971) argues against the stereotype that the products of a supernatural mode of thought are inevitably magical, irrational, and unscientific. He states that, in African traditional thought, supernatural notions have certain important features which, when critically analyzed, can be said to be objective and, therefore, should not be dismissed as irrational. Certainly, an understanding and a distinction of what constitutes supernatural and natural ways of explaining and understanding natural phenomena is critical in the evolution of appropriate science curricula (Gitari, 2003). This is more so because, within African philosophy, both the natural and supernatural are viewed as interwoven in causal explanation and understanding of natural phenomena. Similarly, writing in the context of health and healing, Gbadegesin (1991) argues that supernatural and natural explanations provide a range of evidence from which people explain and understand natural phenomena.

In another context, Kilbourn (1980) has shown that students' world views do influence their understanding of scientific concepts. Further, in a study to investigate the relationship between African traditional cosmology and students' acquisition of a science process skill, Jegede and Okebukola (1991) concluded that "correct" scientific observations are dependent on students' beliefs. African traditional cosmology[3] was understood to shape how students explained natural phenomena; students used this cosmology as a conceptual framework for constructing personal ideas about natural phenomena.

One way to begin understanding the ideas students have about natural phenomena is to refer to the root metaphors that prevail in their world views. A root metaphor provides the "basic material out of which all the facts of the universe can be generated" (Pepper, 1970, p. 93). When such facts are available, they are organized in a meaningful way in reference to the existing socio-cultural milieu of values, beliefs, and myths (Ogunniyi et al., 1995). The totality of facts that emanate from a root metaphor, and their entire organization within the socio-cultural milieu, constitutes the person's world view. In a broader sense, a community of people with similar socio-cultural and historical backgrounds could be said to have a world view. A people's world view is central to the way they understand and explain natural phenomena. Subsequently, a world view influences the way people construct and validate knowledge, including scientific knowledge. As already stated, the assumption that all scientific knowledge is objective and thereby universal has been strongly challenged. What has resulted from this challenge is a growing interest in the notion of a multicultural, anti-racist, and anti-sexist science. Interest in the latter notions of science also comes from the realization that a large proportion of students are not benefiting from the "universal" science.

Feminist and African studies have produced a large body of literature that is concerned with addressing the question, whose science is considered universal or worthy science? It is important to note that women's studies and African studies have a common heritage in the popular movements of the 1960s and 1970s, which led to a critique of the modernization theory that perceived society as if on a linear path from "traditional" to "modern" environments (Stamp, 1989). The implications of this dichotomy are that "traditional" is viewed as fossilized, belonging to the sphere of women and non-progressive, while "modern" is regarded as progressive, belonging to the West and in the public or male domain (Robertson, 1987). In this respect, indigenous practices are seen as obstacles to progress. Such a view denigrates indigenous practices by rendering them unsuitable for progressive considerations such as modern schooling. Also, it equates modern with Westernization, thereby implying that non-Western societies do not contribute to the "modern." Furthermore, it depicts modern science and technology as solely a Western heritage. Harding (1991) and Warren et al. (1995) argue that, although a Western world view predominates modern science, modern science (especially biology and medicine) has benefited from different world views of various international communities found within institutions of higher learning throughout the world.

Arguments such as those offered by Harding (1991) and Warren et al. (1995) are based on the notion of alternative sources of knowledge production and validation that are outside existing Eurocentric frameworks. Models of teaching science in Africa are historically related to the colonial experience of the early nineteenth to the mid-twentieth centuries. The colonial experience "damaged" indigenous knowledge (local knowledge that is unique to a given culture or society) to the extent that even today it is not legitimized at the high-school level (Gitari, 2003). This is because indigenous knowledge is said not to meet the standards of high-school science. Yet, as postcolonial discourses indicate, standard ways of doing things often reflect hegemonic perspectives of certain powerful groups. As such, it is worthwhile for researchers to interrogate alternative ways of doing things. In the context of schooling, alternative ways of doing things are sought when people are faced with everyday problems whose solutions are not attainable solely with the help of scientific knowledge acquired at school. Indeed, it is becoming increasingly clear that the transfer of school knowledge to out-of-school contexts is not the result of simply being trained in science.

KNOWLEDGE ADAPTATION

It is not fully understood why science graduates rarely find it useful to draw upon knowledge or skills acquired during schooling; yet knowledge and skills acquired informally seem to be used in a variety of everyday problem-solving situations. For instance, it has been noted that in Africa most learners retain indigenous notions of natural phenomena in spite of the content of school science. For example, in a study on the everyday use of scientific knowledge among Sotho

(South Africa) men and women who had previously acquired the scientific notion of heat, Hewson and Hamilyn (1985) found that both genders largely applied the traditional heat metaphor as a conceptual tool in explaining the phenomenon of heat, instead of the notion of heat acquired in their schooling. A study of how Tanzanian teachers linked local technology to school science revealed that few teachers in very few instances used school science language (scientific terms) to describe the traditional fermentation process (Knamiller et al., 1995). The study revealed a clear disconnection between school science and everyday problem-solving. Further, Knamiller posits that "much of the knowledge and certainly the perceptions that African children have of science are wrapped up in their experiences with the happenings that surround them in their local communities" (p. 68).

Examining the transfer of knowledge from school contexts, such as the laboratory, to non-school contexts, such as the workplace, has generated an interesting body of literature. One consistent observation is that

> … thinking is intricately interwoven with the context of the problem to be solved. The context includes the problem's physical and conceptual structure as well as the purpose of the activity and the social milieu in which it is embedded. One must attend to the content and the context of intellectual activity in order to understand thought processes. This is the case for any situation in which thinking is studied, including the laboratory context, which is not context-free as researchers frequently assume. (Rogoff, 1984, pp. 2–3)

As Rogoff points out, cognitive skills are limited in their generality and a skill developed within a laboratory situation may not serve a useful purpose outside that context. In laboratory settings science experiments are routinely performed and, compared to learning contexts in everyday life, lack emotive events or story-specific episodes that help in knowledge acquisition (Hodson, 1988).[4] The integration of school knowledge into everyday social interactions is what makes school knowledge relevant. This approach is associated with Dewey's 1916 monograph on interest and effort. Dewey's philosophy of education would later address knowledge discontinuity by focusing on individual interests in learning, a learner-centred orientation.

The importance of relevance in education cannot be overstated. The observation that nearly all formal curricula have official goals that aim to enable learners to use knowledge and skills acquired during schooling in everyday life underscores this valued position. However, such official positions are informed by different opinions of what schools should be doing, that is by conservative, liberal, or radical views of schooling (Giroux & Simon, 1989). Therefore, it is not enough to desire knowledge transferability in learners; indeed, the underpinning ideologies that concern such a desire should be explicated and problematized since curriculum goals act as a form of educational accountability, which is a necessary step if relevance is to be achieved.

Making certain that school science is put into practice is another form of educational accountability. Putting science into practice may necessitate the merging of science and technology within the science curriculum, consequently, giving learners a forum for using science skills in everyday life problem-solving. Besides, the separation of science and technology is not by virtue of a distinctive operating procedure or a conceptual framework; rather, this separation exists because of different goals (Cajas, 2001; Layton, 1991; Hodson & Reid, 1988). At the theoretical level the primary goal of science is knowing *that*, whereas the primary goal of technology is knowing *how*, that is, finding practical solutions to everyday problems (Hodson, 2003; Jenkins, 2003). But in practice, the historical development of science and technology reveals an intricate and diffuse relationship consisting of incidences where (1) the invention of technological devices aided in scientific discoveries, (2) scientific discoveries were first made before the invention of technological devices that would later help in explaining and advancing the discoveries, (3) technological innovations and scientific discoveries were independent of each other, and (4) scientific discoveries and technological innovations were mutually dependent on each other (Hodson, 2003).

In addressing the problem of applicability, one may begin by asking why science is not taught along with technology, and whose interests are served when science is taught as distinct from technology (Hodson, 2003). Although answers to these questions are beyond the scope of this chapter, posing them helps one to reflect on other important aspects of the science pedagogy debate. Also, to ponder such basic questions is to initiate discussion of the history of school science and technology in Africa.

The history of school science and technology dates back to the colonization of Africa. The spread of modern science and technology from Europe to Africa by way of colonialism and neo-colonialism was overly successful, perhaps because the vandalism of colonialism was accompanied by industrial and capitalist institutions of modernity into which science and technology were woven. The spread of modern institutions across the world, originally a Western phenomenon, made Western expansion seemingly irresistible (Geddis, 1990). This spread also destroyed the indigenous technological basis of many African societies (see Ocaya-Lakidi & Mazrui, 1975). Urevbu (1991) also argues that "Africa possessed a technological base on which a technological revolution and successful industrial development might have been achieved, but for the historical disaster of slavery" (p. 71).

In Africa, foreign science and technology were more successful in transferring their products and consumption than their essence, therefore becoming a liability (Ocaya-Lakidi & Mazrui, 1975; Blackett, 1969). Unlike most other foreign concepts, for example, the teaching of liberal arts, which were readily Africanized, "science" has remained a foreign form of knowledge, probably because science and technology are forms of knowledge whose development require a context where there is indelible harmony between values and skills (Mazrui, 1978). This observation underscores the need to contextualize scientific knowledge, as discussed earlier. Even as concerns for gender equity, knowledge contextualization, and knowledge adaptation take centre stage in Africa, educators express the need for more appropriate teaching approaches. Traditional teaching approaches (for instance, didactic process and discovery learning) depict scientific knowledge as absolute and unproblematic. They also have not enhanced knowledge transfer for effective socio-economic changes and are therefore inadequate to meet current needs. In view of this, African educators see the need to experiment with more appropriate teaching and learning approaches to overcome gaps and inadequacies.

EDUCATION WITH PRODUCTION (EWP)

Education with Production (EwP) "refers to arrangements whereby socially and economically meaningful components of production have been combined with education or training" (Hoppers & Komba, 1995, p. 9). EwP is different from vocational training in its philosophy and practice. Vocationalization aims to prepare students for work by incorporating work-related skills, for instance, needle work, carpentry, and masonry, into general education, whereas EwP advocates self-reliance through the incorporation of an "educative value of work" in the general curriculum and through adopting a participative role within the community. EwP is linked to the populist traditions that stemmed from dissatisfaction with the outcomes of formal schooling (where students were alienated from their communities) and rapid changes in socio-economic environments. In developing countries, populist traditions were based on the ideas of national leaders such as Mahatma Gandhi of India or Julius Nyerere of Tanzania (Hoppers & Komba, 1995). In North America, populist traditions found expression in the progressive movement of the 1930s and later in colleges that taught work skills created to cater to youth unemployment in the 1970s and 1980s. But, as employment opportunities improved, such programs lost their focus and were incorporated into general curricula as careers and guidance programs.

In Africa, manual labour has long been viewed as undesirable, a view that has a lot to do with the history of formal schooling. During colonial times, Africans were trained for manual labour because Europeans believed that manual labour matched the intellectual capabilities of indigenous Africans. In view of this, the use of EwP in Africa should be twofold: to offer learning experiences that reflect the philosophy of indigenous education where theory and practice go hand in hand, and to incorporate productive work in general schooling as a basis for moving away from current methods, structures, and goals of learning. Other purposes of EwP should be:

- the reduction of incidences of rural-urban migrations by developing in students, teachers, and members of the local community a broad range of practical and problem-solving skills or relevant production skills;

- lowering barriers between school and the local community by directly introducing learners to the realities of work; and
- enhancing character development in learners.

EwP is not without disadvantages. For instance, because children are involved in productive labour, care must be taken not to exploit them for cheap labour. Sometimes EwP has been used to justify tracking in the classroom, that is, categorizing students into those who are ready for academic disciplines and those who are not. The end result is that certain groups of children are trained for elite professions while others are prepared to serve in the lower cadres of the socio-economic structure. In view of its potential misuse, those who advocate EwP stress the need to reconceptualize and problematize the concept over time to reflect changes in political, social, and economic aspects of individuals and their communities (Hoppers & Komba, 1995). Such reconceptualization may enable those involved in the implementation of EwP to avoid tracking and exploitation. When used as a framework with which to provide meaningful education, EwP can enhance the learning process in various ways (Van Rensburg, 2005).

EwP can create direct benefits to science teaching and learning when the content of science is drawn from and linked to local scientific knowledge. This could possibly happen as teachers and students grapple with ways in which to apply theory to practice within the local community in the context of existing productions or in the creation of new productions. For the purposes of instruction, teachers could draw materials, expertise, and practical and theoretical knowledge from the local community. Consequently, students could gain respect for knowledge that emanates from the local community and in so doing be able to build a context from which to draw intellectual inspiration and test problem-solving skills.

Finally, EwP has the potential to alter the gender equation in science. For example, girls working in science-related productions may be encouraged to change their minds about pursuing science as a career. A hands-on experience in repairing a car engine, for instance, may not only link theoretical knowledge to real-life situations, it may also make the unfamiliar familiar. Solutions to real-life situations and familiarity with the theoretical aspects of practice and vice versa are two elements that make science more meaningful to girls (Sjøberg, 2001; Solomon, 1994). Whereas EwP makes scientific concepts commonplace and recognizes indigenous knowledge, it does not address aspects of teaching and learning that deal with how students come to know; therefore, such issues may be addressed through constructivist teaching (Jenkins, 2003).

CONSTRUCTIVIST TEACHING

Underlying the constructivist paradigm is the understanding that learners actively build knowledge based on their interactions with physical events in daily life (Bereiter, 1994; Falk & Adelman, 2003). The nature and quality of students' constructions are taken as a general orientating framework for instructional purposes. Such frameworks embody clear strategies for influencing conceptual change and problem-solving attitudes.

One area in which constructivist teaching could be used to redress science education problems is in promoting a view of science that encourages teachers to take note of students' observations and experiences of natural phenomena. For instance, students bring to science lessons their own observations or experiences that are based on a world view derived from the social environment in which they grew up. To that end, the aim of a planned learning activity should not be to replace prior experiences with scientific facts. Rather, it should be to isolate students' observations or experiences of natural phenomena and to (1) present scientific claims and discussion on how scientific claims are similar or different from students' experiences; (2) discuss which explanations and observations are more plausible and give reasons why; (3) explore the reasons for adopting one way of explaining and rejecting others, or the values of retaining all explanations; and (4) stimulate discussions on the application of different explanations for real-life situations.

This process of knowledge construction is also suitable for importing practical knowledge into the theoretical aspects of any science lesson. Practical knowledge refers to the skills that students use to design, make, or improve artefacts, and the knowledge students' use in their day-to-day life to explain and understand natural phenomena. Such a process of knowledge construction will, therefore, enable the technology component of science to be drawn into discussions, thus facilitating the teaching of technology alongside science. An incorporation of technology into science lessons is attractive to students who value a practical element in learning.

Girls, for instance, are said to value the component of technology in science (Sjøberg, 2001); therefore, they are likely to find a constructivist approach amenable in rebuilding the "intimate association of knowing and doing" (Layton, 1991, p. 44). To that end, constructivist teaching is suitable for redressing this issue of knowledge adaptation as well as adopting science teaching strategies that inhere in women's ways of knowing. Because the process of knowledge construction allows one to move, conceptually, from what one knows to what one does not know, it is a method that enables students to debate and examine other world views, become conversant with their own world views, and appropriate other world views.

One drawback of constructivist teaching is its tendency to focus on the constructions of the individual while not paying equal attention to societal factors. Adhering to a constructivist approach exclusively has the potential of taking note of students' constructions without necessarily helping students understand how these constructions have come about. Societal factors have a direct bearing on the knowledge that students, and anyone else including scientists, construct: therefore, societal factors should be incorporated into science lessons.

Incorporating a discussion of the social, environmental, economic, and political factors that influence the building of knowledge is important. It is particularly important for students to gain insight into how scientific knowledge is constructed. Constructivist teaching is limited in this regard. Other teaching approaches such as Science, Technology, Society and the Environment (STSE) and anti-racism, are better able to bring these factors into a science lesson. STSE teaching incorporates the societal and environmental dimensions in developing science concepts, while anti-racist teaching critiques societal conditions under which knowledge is constructed.

SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT (STSE)

Teaching science through STSE ensures that meaningful context and evaluative dimensions of technology, society, and the environment are included (Hodson, 2003; Solomon, 1994). Sociological, historical, and philosophical aspects of the epistemology of science and other sub-disciplines, like economics, sociology, and politics inform this approach. The emphasis is on science subject matter and skills, their connection to the student's everyday life and the politicization of science education contexts followed by social action (Hodson, 2003; Solomon & Aikenhead, 1994). Instructional approaches ensure that students make *personal* sense out of science concepts and develop "higher reasoning capabilities associated with creativity and critical thinking" (Aikenhead, 1988, p. 4).

Arguably, STSE has the potential for making epistemological, historical, and cultural arguments of how substantive structures of scientific knowledge are constructed and of how they come to be known to science teachers and students. An understanding of the factors that influence the building and testing of theory, the relationship between theory and observation, the place of models, theories, experiments, and logic in the building of scientific knowledge is likely to happen through the study of the history, philosophy, and sociology of science as offered in STSE courses. By laying out fundamental concepts, principles, and processes on which scientific knowledge is based, STSE sets the stage for an articulation of the scientific world view, while helping students explore their own world views. Such an exploration provides students with the knowledge and skills with which to integrate scientific concepts into other world views, without a sense of alienation and confusion (Aikenhead & Jegede, 1999).

An explication of the fundamental concepts, principles, and processes of science will lead to a better understanding of the nature of science, especially with regard to the role of theory in the building of scientific knowledge. In science text books, for instance, observations of phenomena are not preceded by an explanation of the theory that supports such observations. Overall, there is a tendency to separate theory from observation. What such a distinction does is to encourage students to *observe* or *discover* natural phenomena and scientific concepts without an in-depth understanding of the guiding principles and underlying frames of reference in scientific inquiry (Hodson, 1988).

STSE also enables students to begin to explore current gender inequity in science. An understanding of how women are socialized could enable them to reconsider their career choices and actively challenge the social markers that structure their subjugation. However, overall STSE is limited in fully *questioning* current structural and systemic dimensions of power, economics, and the cultural domination in which science discourses happen, a dimension that is the focus of anti-racist science teaching.

ANTI-RACIST SCIENCE TEACHING

The underlying strategy of anti-racist teaching is to problematize the taken-for-granted, to subvert hegemonic traditions, and to foster an informed interest in science while at the same time challenging racist attitudes and their origins. The discourse levels of an anti-racist approach are instructional, transactional, and interactional (Dei, 1994; Nyamnjoh, 2004). This approach is suitable as a tool for reconstructing the context within which science discourses happen. For instance, based on a study conducted in Britain by Gill, et al. (1987) four key issues should be addressed by an anti-racist perspective in science: "(i) the colonial history which underlies racism in British society; (ii) the devaluation of 'non-Western' cultures; (iii) development and underdevelopment; (iv) racism in contemporary society" (p. 173).

The anti-racist approach could be used to examine curricula materials for sexist views, to encourage students to question traditional ways of viewing women as passive and as having intelligence inferior to men, and for considering science as a preserve for men. Epistemologically, educators could revise all instructional materials to rid them of existing content biases and ideologies of racism, sexism, and classism. Similarly, educators could examine and question where school science comes from and why, and by so doing help foster students' critical skills so that they can make more informed choices in their lives.

The value of anti-racist teaching in redressing issues of knowledge adaptation is founded on its focus on empowerment, which ensures that students' critical and creative skills are directed toward reclaiming their heritage. Students' knowledge of the colonial history of science education in Africa and the damage inflicted on indigenous knowledges by colonial practices help students to see science as a human construction. Most importantly, they see the value in their cultural knowledge and the potential for its further development. Consequently, students come to see the need for creating knowledge and skills that are appropriate for their environment and relevant to everyday problem-solving. Anti-racist teaching is easily carried out when students are in small groups. This ensures that students explore and express their experiences within the curriculum. Small group learning, also referred to as co-operative learning, provides for the creative and constructive exploration of experience.

CO-OPERATIVE LEARNING

Co-operative learning is the use of small groups as a strategy to enhance instruction, problem-solving, classroom management, and instilling social consciousness (Schniedewind, 2004). This approach is based on the notion that knowledge acquisition requires a climate where the creators of knowledge can represent events, negotiate meaning, and agree on acceptable views (Wells et al., 1990). Co-operative learning has a very long history and is widely used – for example, when small groups are used as an instructional strategy or when a team of people are brought together by the need to resolve a problem. These are common occurrences in school and in out-of-school settings all over the world. Noteworthy is that research on co-operative learning has only emerged within the past two decades, necessitated by the realization that co-operative learning may be deployed as an approach for resolving many challenges prevalent in schools today. Some of the many benefits of co-operative learning are that it:

1. enhances self-esteem by promoting mutual support and the exchange of ideas, thereby stimulating students' interest in learning;
2. improves achievement because it enables students to reflect on their study skills, mastery and retention, quality of reasoning strategies, new ideas and solutions (Johnson & Johnson, 1990);
3. enables the teacher to cater to individual interests in relation to the abilities of other students;
4. improves classroom management; and,
5. enhances socialization, especially in ethnically heterogeneous classrooms.

Notably, few studies address science-related disciplines (Okebukola & Ogunniyi, 1984). For the purposes of this discussion, co-operative learning could be used in a science class as a basis for generating indigenous notions of how people explain and understand natural phenomena. In small group settings, students could be encouraged to share their views and develop more acceptable ideas about indigenous science. Students could plan to test some of these ideas through experimentation, leading to revision and further testing of the ideas. In so doing they re-enact processes and procedures that are encountered in the production and validation of school scientific knowledge.

Sherman (1994) observed that co-operative learning can help to "achieve a variety of academic and social goals in the classroom setting" (p. 226). For instance, in the safety of small groups, issues which emanate from the study of the history, philosophy, and sociology of science (e.g., gender issues) would be more likely to stimulate productive discussions than when the entire class is involved. Johnson and Johnson (1990) have observed that individuals in co-operative learning groups use elaborative and metacognitive strategies more frequently than individuals working competitively and individualistically and therefore perform at a higher level.

A drawback of co-operative learning is that it could encourage "free riders" – those who could get away with doing less would do less than others. This could cause more productive group members to work less in order to avoid being taken advantage of. This dynamic of course would have detrimental effects on the entire co-operative process. However, as already stated, there are many benefits – development of skills, stronger and deeper insights, team solidarity, and so on – all of which enhance the learning experience and override the drawbacks (Iwai, 2004). Because of this, co-operative learning could be used to enhance the effects of EwP, constructivist teaching, STSE, and anti-racist science teaching.

As the twenty-first century advances, questions of how to deal with gender, knowledge application, and epistemology remain unanswered. Undoubtedly, some of the current constraints of science education in Africa are rooted in the nature of science content and the context in which science is learned. Regrettably, constraints of science education militate against desirable outcomes, such as the promotion and the acquisition of creative abilities and critical skills, the linkage between scientific knowledge and skills and problem-solving. Nevertheless, there is hope that the appropriate teaching strategies discussed in this chapter can overcome some of these problems. EwP provides a hands-on experience in learning, while co-operative learning enhances self-esteem in students and facilitates the learning of subject matter. Anti-racist teaching enables students and teachers to deconstruct and radicalize the milieu of science discourses, while constructivist teaching and STSE approaches are progressive techniques for learning science concepts. As well, these learning approaches appeal to women's ways of knowing, helping girls and boys to place science within the context of everyday life, and teaching them how to construct knowledge that is applicable in everyday problem-solving.

STRATEGIC INTERVENTIONS AND FUTURE DIRECTIONS: TRANSFORMATIVE AND SUSTAINABLE SCIENCE EDUCATION

This chapter has highlighted two major issues of science education in Africa, namely gender inequality and the apparent lack of knowledge application to everyday life. The chapter has made suggestions of how to redress the two issues through teaching approaches: Education with Production, constructivist teaching, Science, Technology, Society, and Environment instruction, co-operative learning and anti-racist teaching. In the last several decades these two issues of science education significantly informed science education research and policy activities in Africa. Perusing the documents of the Association for the Development of Education in Africa (ADEA), one frequently encounters the issues of gender and knowledge application; however, by far, gender is the most targeted of the two issues.

For instance, a sub-group of ADEA's working group, Working Group for Female Participation (WGFP) convened by Rockefeller and led by the Norwegian Agency for Development Cooperation (NORAD), focuses on women's participation in science, mathematics, and Technology. The WGFP has promoted gender fair science curricula in countries such as Cameroon, Ghana, Tanzania, and Uganda, through the gender, math, and science project known as Female Education in Mathematics and Science in Africa (FEMSA) (Sjøberg, 1998). The Forum for African Women Educationalists (FAWE) is a lead agency in FEMSA's activities. Although FAWE activists do not specifically target science education, their projects and policy activities impact access and achievement of girls in education in general.

In addition to FEMSA's efforts, there are other forums and organizations solely devoted to gender issues in science education. Sjøberg (1998) provides an extensive list of organizations and forums that focus on promoting gender equity in education, all of which are indicative of the important initiatives being made towards addressing issues of gender and science education in various regions of Africa. This list of gender-focused forums include: Girls and Science and Technology (GASAT), in Ghana in 1999, and the International Organization for Science and Technology Education (IOSTE) hosted in Durban, South Africa, in 1999. Other organizations include the African Forum for Children's Literacy in Science and Technology (AFCLST) located in South Africa and Malawi and United Nations Educational, Scientific and Cultural Organization (UNESCO), whose participation in the promotion of women and girls in science is through organizations such as ADEA.

Overall the issue of knowledge application and relevance has significantly inspired policy changes and curriculum restructuring throughout the continent. It is widely recognized that science and technology education will play a key role in the desired socio-economic development of the region (ACTS, 2001; UNESCO, 1999; UNESCO-CAMSTE, 2001). Additionally, the pressing problems of the HIV/AIDS pandemic, abject poverty, and unemployment have reawakened African educators to the notion of relevance and the role that science and technology will play in resolving the problems

(ADEA, 2005). Of course the need for relevant science education in Africa is not new. For instance, the history of curriculum restructuring in East Africa is marked by recurring reference to the application of school science in everyday life (Bogonko, 1992a). Moreover, Kenya's curriculum restructuring in the 1980s was mainly to redress the problem of irrelevance. In particular, science and technology education were targeted as needing special consideration. It was declared that science and technology instruction be geared to the needs of local communities. Unfortunately, the complete and effective implementation of the science curriculum was hindered by an unrealistic time frame, bureaucracy, lack of teacher preparedness, and lack of materials and laboratory equipment, among other obstacles (Bogonko, 1992b). In a similar way, South Africa's learner-centred and society-oriented curriculum implementation has experienced similar setbacks (Howie, 2002).

Problems that hinder complete and effective curricula implementation are widespread across Africa. The World Bank (2002), for instance, discusses the need to critically re-evaluate teacher education/preparedness, teaching methods, pupil assessment, curricula relevance, and learning materials. Stressing the urgent requirement for the re-evaluation of science education in Africa, the World Bank also acknowledges obstacles that will demand concerted effort in policy implementation and generous allocation of funds to the science education sector. Noting that in 1998 in Botswana 56 per cent of science and mathematics teachers were expatriates, the World Bank asserts that "science education has only deteriorated over the last decade in most African countries" (2002, p. 17). This is especially deplorable because of the urgency to contextualize and to utilize the new technologies, namely biotechnology and Information and Communications Technologies (ICTs) to alleviate the enduring socio-economic, health, and environmental problems. In a report prepared by the African Centre for Technological Studies (ACTS), there is a firm call to plan and mobilize resources in time for the anticipated rapid growth of both ICT & biotechnology (ACTS, 2001; UNESCO, 1999).

Indeed, it is a sombre picture for science education in Africa. Nevertheless, it is evident from current literature that teachers in African may be utilizing some of the teaching approaches that were outlined earlier in this chapter (ADEA, 2005). Chepyator and Thomson (2005) reported that primary and secondary teachers in the Keiyo district of Kenya use cultural knowledge among their students to help in the construction of scientific knowledge. Keiyo teachers used community-based learning opportunities to teach science to students. And, although teachers in Africa may not label their pedagogical strategies as anti-racist teaching, STSE instruction, constructivist teaching, or co-operative learning, their efforts are laudable and do resemble some of these methods. Teachers in Africa contextualize science learning and use available resources to help their pupils acquire relevant knowledge. In regard to contextualized science content, Sjøberg (2000) demonstrated that cultural knowledge is a key factor in the way pupils view science content and learning and that the use of cultural knowledge in science learning is therefore likely to impart relevance to the subject matter.

In regard to the identification of the teaching methods that teachers use in their classrooms, Education with Production (EwP) is unlike the other teacher approaches described in this chapter. The use of EwP is easy to identify because of its distinct feature production. EwP also has a long-standing presence in Africa and there is evidence that educators and policy-makers in Botswana, Lesotho, Zambia, Zimbabwe, and South Africa are utilizing EwP to enhance the application of science subject matter to everyday life (Van Rensburg, 2005).

It is indisputable that teachers everywhere in Africa are, in one way or other, doing their best to make science relevant to their students. The question, however, is to what extent are teaching methods such as EwP, constructivist teaching, STSE, anti-racist science teaching, and co-operative learning utilized to enhance gender equity and knowledge application? Although the argument is strong for these teaching approaches as desirable methods to address gender inequality and knowledge application, it is important to systematically study their efficacy in Africa. It is necessary to document what is really going on in science pedagogy in Africa by doing classroom observations or conducting inquiries among teachers. Such studies of pedagogy are rare and are rarely duplicated. A study like the one conducted by Ogunniyi's (2005) is worth duplicating. Ogunniyi's study with secondary teachers in South Africa involved a module designed to find out the extent to which teachers were aware of their pupils' culturally informed learning characteristics. At the end of the study the majority of teachers confessed to having been ignorant of the culturally informed learning characteristics of their learners. Another strategy of gathering data would be a one-time, widespread and systematic study across Africa. The approach used by Sjøberg (2001) in the Relevance Of Science Education (ROSE) project may accomplish the goals of such a systematic regional study. Even more profitable would be to involve teachers in researching their science teaching practices, taking stock and planning changes. Participatory research and action research methodologies may help in accomplishing the goal of training teacher researchers (Hodson, 2003). Informed teachers are equipped to participate in the continued restructuring of the science curricula. Furthermore, they are updated on suitable teaching methods for accomplishing educational goals such as gender equity and knowledge application.

Eventually when science educators, curriculum planners, and policy-makers understand ways in which teachers attempt to eradicate gender inequity and promote knowledge application, they can mobilize resources to give teachers more training and autonomy in the interpretation and implementation of curricula and assessment of pupils. The current standardized national examinations, typically found in most African countries, are not conducive to the kind of teacher creativity implied here. Standardized exams force teachers to rely on textbooks as a sole teaching resource and to gear their teaching toward correct answers to exam questions, inadvertently nurturing a science-centred curriculum and didactic teaching. In a climate of professional autonomy, teachers will be at liberty to experiment and report on the teaching approaches outlined in this chapter, emerging approaches and modules such as the one developed by Ogunniyi (2005), methods of teaching biology like the one authored by Griffiths (2003), or suggestions made by Gitari (2005). Gitari suggested the use of local ways of knowing as conceptual tools for knowledge construction. In her paper she includes questions that teachers can use in planning lesson units.

Finally when teachers are well prepared and there are adequate materials and resources for teachers to effectively engage with science subject matter, it will be worthwhile to reflect on the observation that,

> … whatever learning theory is espoused, the central task of the teacher in promoting learning remains that of choosing and deploying the method(s) most likely to help students learn what the teacher wishes them to know, understand or be able to do. In other words, the relative merits of different teaching strategies are to be judged principally by reference to student learning, although other factors are likely to be involved, such as the facilities and level of resources required, and the implications for class management and assessment. In broad terms, students learn most effectively when they are set *clear objectives*, are *actively involved in their own learning*, appreciate the *relevance of their studies* and receive *regular and constructive feedback* about their progress. (Jenkins, 2003, p. 26; emphasis added)

Equitable, relevant, transformative, and sustainable science education will be accomplished in Africa when the four conditions outlined by Griffith are met; it is then that the desirable "science culture" will emerge (UNESCO, 1999). Eventually, learner-centred and society-oriented curricula will be realized throughout the region.

REFERENCES

ACTS (African Centre for Technology Studies). (2001). Report on the 1st Roundtable on Africa, Science and Technology in the Age of Globalization. Organized by the Africa Centre for Technology Studies in collaboration with the African Technology Policy Studies (ATPS), August 7–8, 2001.

ADEA (Association for the Development of Education in Africa). (2005). *1999 prospective, stock review taking of education in Africa*. Retrieved December 20, 2005, from http://adeanet.org/programs/pstr99/en_pstr99.html.

Aikenhead, G. S. (1988). Teaching science through a science-technology-society-environment approach: An instruction guide. Saskatchewan Instructional Development and Research Unit (SIDRU), Report No. 12, July.

Aikenhead, G., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*(3), 269–87.

Atwater, M. M. (1996). Social constructivism: Infusion into the multicultural science education research agenda. *Journal of Research in Science Teaching, 33*(8), 821–37.

Baker, D., & Leary, R. (1995). Letting girls speak out about science. *Journal of Research in Science Teaching, 32*(1), 3–27.

Bereiter, C. (1994). Constructivism, socioculturalism, and Popper's world. *Educational Researcher, 23*(7), 21–23.

Blackett, P.M.S. (1969). Reflections on science and technology in developing countries. *Gandhi memorial lecture*, University of Nairobi, Kenya. Nairobi: East African Publishing House.

Bogonko, S. (1992a). *A history of modern education in Kenya (1895–1991)*. Nairobi, Kenya: Evans Brothers.

Bogonko, S. (1992b). *Reflections on education in East Africa*. Nairobi, Kenya: Oxford University Press.

Cajas, F. (2001). The science/technology interaction: Implications for science literacy. *Journal of Research in Science Teaching, 38*(7), 715–29.

Chepyator, J. R., & Thomson, N. (2005). Formalization of informal science knowledge in Kenyan Public schools: Teachers' use of indigenous ideas and examples in science subjects. Paper presented at the National Association for Research in Science Teaching (NARST), Dallas, TX, April 4–7, 2005.

Dei, G.J.S. (1994). The challenges of anti-racist education research in the African context. *Africa Development, 29*(3), 5–25.

Dewey, J. (1916). *Democracy and education*. New York: Macmillan.

Dzobo, N. K. (1975). Values and indigenous African education. In G. N. Brown & M. Hiskett (Eds.), *Conflict and harmony in education in tropical Africa* (pp. 76–90). London: George Allen & Unwin.

Eisner, E. (1992). Curriculum ideologies. In P. W. Jackson (Ed.), *Handbook of research on curriculum: A project of the American educational research association* (pp. 302–26). New York: Macmillan.

Falk, J. H., & Adelman, L. M. (2003). Investigating the impact of prior knowledge and interest on aquarium visitor learning. *Journal of Research in Science Teaching, 40*(2), 163–76.

Fensham, P. J. (1988). Familiar but different: Some dilemmas and new directions in science education. In P. J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 1–26). Lewes: Falmer Press.

Gbadegesin, S. (1991). *African philosophy: Traditional Yoruba philosophy and contemporary African realities*. New York: Peter Lang.

Geddis, A. (1990). *The consequences of modernity*. Stanford: Stanford University Press.

Gill, D., Patel, V., Sethi, A., & Smith, H. (1987). Science curriculum innovation at Holland Park School. In D. Gill & L. Levidow (Eds.), *Anti-racist science teaching* (pp. 147–74). London: Free Association Books.

Gilligan, C. (1982). *In a different voice*. Cambridge, MA: Harvard University Press.

Giroux, H. A., & Simon. R. I. (1989). Schooling, popular culture, and a pedagogy of possibility. In H. A. Giroux & R. I. Simon (Eds.), *Popular culture: Schooling & everyday life* (pp. 219–36). New York: Bergin & Garvey.

Gitari, W. (2003). An inquiry into the integration of indigenous knowledges and skills into the Kenyan secondary science curriculum: A case of human health knowledge. *Canadian Journal of Science, Mathematics and Technology Education, 3*(2), 195–212.

Gitari, W. (2005). Everyday objects of learning about health and healing and implications for science education. *Journal of Research in Science Education, 43*(2), 172–93.

Griffiths, A.J.F. (2003). Community-based biology: UNESCO-IUBS Bioliteracy Series No.1. International Union of Biological Sciences. Retrieved June 20, 2005, from http://www.iubs.org/cbe/Community%20based%20Biology.htm.

Harding, J., & Apea, E. (1990). *Women too in science and technology in Africa: A resource book for counselling girls and young women*. London: Commonwealth Secretariat, Education Programme, Human Resources Group.

Harding, S. (1991). *Whose science? Whose knowledge*. Ithaca, New York: Cornell University Press.

Hewson, M.G.A., & Hamilyn, D. (1985). Cultural metaphors: Some implications for science education. *Anthropology & Education Quarterly, 16*(1), 31–46.

Hodson, D. (1988). Experiments in science and science teaching. *Educational Philosophy and Theory, 20*(2), 53–66.

Hodson, D. (1992). *Teaching and learning about science: Considerations in the philosophy and sociology of science*. Manuscript, Ontario Institute for Studies in Education.

Hodson, D. (2003). Time for action: Science education for alternative future. *International Journal of Science Education, 25*(6), 645–70.

Hodson, D., & Reid, D. J. (1988). Science for all: Motives, meanings and implications. *School Science Review, 69*, 653–61.

Hoppers, W., & Komba, D. (Eds.). (1995). *Productive work in education and training: A state-of-the-art in Eastern Africa*. Kortenaerkade 11, Netherlands: Center for the Study of Education in Developing Countries (CESO).

Horton, R. (1971). African traditional thought and western science. In M.F.D. Young (Ed.), *Knowledge and control* (pp. 208–66). London: Collier-MacMillan.

Howie, S. J. (2002). Renewal of Secondary Education Curriculum and Assessment in South Africa. In the World Bank, *Secondary Education in Africa: Strategies for Renewal. World Bank presentations at the December 2001 UNESCO/BREDA-World Bank Regional Workshop in Mauritius on the Renewal of Secondary Education in Africa. Document #25246* (pp. 41–53). Washington, DC: The World Bank.

Iwai, T. (2004). Learning language in cooperatively structured groups in a first-year level university classroom: A case study of Japanese as a foreign language. Thesis, Ontario Institute of Studies in Education, University of Toronto.

Jegede, O. (1994). African cultural perspectives and the teaching of science. In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 120–30). New York: Teachers College Press.

Jegede, O. J., & Okebukola, P. A. (1991). The relationship between African traditional cosmology and students' acquisition of a science process skill. *International Journal of Science Education, 13*(1), 37–47.

Johnson, D. W., & Johnson, R. T. (1990). Cooperative learning & achievement. In S. Sharan (Ed.), *Cooperative learning theory and research* (pp. 23–37). New York: Praeger.

Jenkins, E. W. (2003). Guidelines for policy-making in secondary school science and technology education. UNESCO, Division of Science, Technology and Vocational Education; Section for science and technology education. Retrieved June 20, 2005, from http://portal.unesco.org/education.

Keller, E. F. (1989). The gender/science system: Or, is sex to gender as nature is to science. *Reflections on gender and science*. New Haven, CT: Yale University Press.

Kilbourn, B. (1980). World views and science teaching. In A.H Munby, G.W.F. Orpwood, & T. L. Russel (Eds.), *Seeing curriculum in a new light: Essays from science education* (pp. 34–43). Toronto: OISE Press.

Kinyanjui, K. (1985). Secondary school education for girls in Kenya: The need for a more science-based curriculum to enhance women's greater participation in development. *Working Paper No. 459*, IDS Nairobi, Institute for Development Studies, University of Nairobi.

Kinyanjui, K. (1993). Enhancing women's participation in the science-based curriculum: The case of Kenya. In J. K. Conway & S. C. Bourque (Eds.), *The politics of women's education: Perspectives from Asia, Africa and Latin America* (pp. 133–148). Ann Arbor: University of Michigan Press.

Knamiller, G. W., O-saki, K. M., & Kuonga, H. C. (1995). Tanzanian teachers' understanding of the science embedded in traditional technologies: A study to inform teacher education. *Research in Science & Technological Education, 13*(1), 67–76.

Kuhn, T. S. (1970). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Layton, D. (1991). Science education and praxis: The relationship of school science to practical action. *Studies in Science Education, 19*, 43–97.

Mazrui, A. A. (1978). *Political values and the educated class in Africa*. Berkeley: University of California Press.

Murfin, B. (1994). African science, African and African-American scientists and the school curriculum. *School Science Mathematics, 94*(20), 96–103.

Nyamnjoh, F. B. (2004). A relevant education for African development – some epistemological considerations. *African Development, 29*(1), 161–84.

Ocaya-Lakidi, D., & Mazrui, A. A. (1975). Secular skills and sacred values in Uganda schools: Problems of technical and moral acculturations. In G. N. Brown & M. Hiskett (Eds.), *Conflict and harmony in education in tropical Africa* (pp. 278–95). London: George Allen & Unwin.

Ogunniyi, M. B. (2005). The effect of a science module on in-service teachers' ability to implement an integrated science-indigenous knowledge curriculum. Paper presented at the National Association for Research in Science Teaching (NARST), Dallas, TX, April 4–7, 2005.

Ogunniyi, M. B., Jegede, O. J., Ogawa, M., Yandila, C. D., & Oladele, F. K. (1995). Nature of worldview presuppositions among science teachers in Botswana, Indonesia, Nigeria, and the Philippines. *Journal of Research in Science Teaching, 32*(8), 817–31.

Okebukola, P. A., & Ogunniyi, M. B. (1984). Cooperative, competitive, and individualistic science laboratory interaction patterns: Effects on students' achievement and acquisition of practical skills. *Journal of Research in Science Teaching, 21*(9), 875–84.

Pepper, S. C. (1970). *World hypothesis*. Berkeley: University of California Press.

Reiss, M. J. (1993). *Science education for a pluralist society*. Philadelphia: Open University Press.

Robertson, C. (1987). Developing economic awareness: Changing perspectives in studies of African women, 1976–1985. *Feminist Studies, 13*(1), 97–135.

Rogoff, B. (1984). Introduction: Thinking and learning in social context. In B. Rogoff and J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 1–8). Cambridge, MA: Harvard University Press.

Rose, H. (1994). The two-way street: Reforming science education and transforming masculine science. In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 155–66). New York: Teachers College Press.

Schniedewind, N. (2004). Educating teachers for socially conscious cooperative learning. In E. G. Cohen, C. M. Brody & M. Supon-Shevin (Eds.), *Teaching cooperative learning: The challenge for teacher education* (pp. 47–64). New York: State University of New York Press.

Sertima, V. (Ed.). (1983). *Blacks in science: Ancient and modern*. New Brunswick, NJ: Transaction Books.

Sherman, S. J. (1994). Cooperative learning and science. In S. Sharan (Ed.), *Handbook of Cooperative Learning Methods* (pp. 226–44). London: Greenwood Press.

Solomon, J. (1994). Learning STS and judgment in the classroom: Do boys and girls differ. In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 141–54). New York: Teachers College Press.

Solomon, J., & Aikenhead, G. (Eds.). (1994). *STS education: International perspectives on reform*. New York: Teachers College Press.

Stamp, P. (1989). *Technology, gender and power in Africa*. Ottawa: International Development Research Center.

Sjøberg, S. (1998). The access of girls to science and technology. In M. B. Ogunniyi (Ed.), *Promoting Public Understanding of Science and Technology in Africa SSME* (pp. 233–60). University of Western Cape, South Africa.

Sjøberg, S. (2000). Science and Scientists: The SAS-study. Cross-cultural evidence and perspectives on pupils' interests, experiences and perceptions. Background, development and selected results. http://www.uio.no/sveinsj/SASweb.htm.

Sjøberg, S. (2001). A comparative and cooperative international study of the contents and contexts of science education. Retrieved December 7, 2005, from http://folk.uio.no/sveinsj/SASweb.htm.

UNESCO. (1999). Basic sciences for development of Eastern and Southern Africa. Retrieved December 20, 2005, from http://www.unesco.org/science/wcs/meetings/agr_arusha_99.htm.

UNESCO. (2004). *Connect, International Science, Technology and Environment Education Newsletter, 29*(3–4). Retrieved June 20, 2005, from http://portal.unesco.org/education.

UNESCO-CAMSTE. (2001). Science, technology and mathematics education for human development: Framework for action. Adopted at *The international Experts Conference on Science, Technology and Mathematics Education for Human Development*, Goa, India, February 20–23, 2001.

UNICEF. (1991). *The girl child: An investment in the future*. New York: UNICEF.

Urevbu, A. O. (1984). School science curriculum and innovation: An African perspective. *European Journal of Science Education, 6*, 217–25.

Urevbu, A. O. (1991). Impact of science and technology on everyday life: An African perspective. *Impact of Science on Society, 161*, 69–79.

Van Rensburg, P. (2005). Is the education fraternity ready for Thuto Le Tiro. *Mmegi, 22*, No. 186. Retrieved December 29, 2005, from http://www.mmegi.bw.

Vance, M. (1987). Biology teaching in a racist society. In D. Gill & L. Levidow (Eds.), *Anti-racist science teaching* (pp. 107–23). London: Free Association Books.

Warren, D. M., Slikkerveer, L. J., & Brokensha, D. (1995). Introduction. In D. M. Warren, L. J. Slikkerveer, & D. Brokensha (Eds.), *The cultural dimension of development: Indigenous knowledge systems* (pp. xv–xviii). Exeter, UK: The LEAD Programme of Leiden University in the Netherlands.

Wells, G., Chang, G.L.M., & Maher, A. (1990). Creating classroom communities of literate thinkers. In S. Sharan (Ed.), *Cooperative learning theory and research* (pp. 95–121). New York: Praeger.
Woodhouse, H., & Ndongko, T. M. (1993). Women and science education in Cameroon: Some critical reflections. *Interchange, 24*(1–2), 131–59.
World Bank. (2002). *Secondary Education in Africa: Strategies for Renewal. World Bank presentations at the December 2001 UNESCO/BREDA-World Bank Regional Workshop in Mauritius on the Renewal of Secondary Education in Africa. Document #25246*. The World Bank: Washington, DC.
Yakubu, J. M. (1994). Integration of indigenous thought and practice with science and technology: A case study of Ghana. *International Journal of Science Education, 16*(3), 343–60.

Notes

1 A "natural phenomenon" is defined as a physical event or experience that is apparent to the senses.

2 I use the term "African" to refer to a world view that may be prevalent within the African region, even as I am aware of the diversity and complexity of the numerous ethnic communities that make up African peoples. My position is that diversity should not negate the common threads of principles seen to guide African thought throughout the centuries (see Dzobo, 1975, p. 77, for a list of these principles).

3 African traditional cosmology refers to existing ways, over time, in which Africans have organized, explained, and understood the origin and structure of the universe.

4 Elsewhere, Hodson (1992) argues that unless *doing* science is linked to learning *about* science, then distraction and alienation may be the *real* outcomes of practical experiments.