Contemporary Issues in African Sciences and Science Education

Akwasi Asabere-Ameyaw, George J. Sefa Dei and Kolawole Raheem (Eds.)

Foreword by Jophus Anamuah-Mensah

SensePublishers

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This work stands as a credit to the many scholars willing to share their knowledge from different locations on the complicated subject of African science education. In many ways, we believe our contributors have something valuable to say on the topic and our job has simply been to assemble their ideas into what we hope will be seen as a coherent piece. Anyone who has put together such a volume knows it is a tremendous challenge and opportunity. We thank the many countless individuals, colleagues, family and friends who have assisted us in this endeavour to put together the edited collection. We have been lucky to the inter-disciplinary edge and lens to the topic which in a number of ways have helped inform our own thoughts and ideas on the subject. Our contributors are engaged in some exciting work on African education and the perspectives they have shared on science education in African contexts can only help build and strengthen existing scholarship in the area. We would like to thank colleagues at our various institutions and our collective conversations that have informed the presentation of an intellectual vision for the collection. There are many but permit us to mention a few**:** Mr. Stephen Dennis, Dr. Thomas Tachie Young, Emmanuel Kutorglo, Marlon Simmons, Jagjeet Gill, Dr. Rosina Agyepong and Isaac Darko. We are also grateful to Professor Jophus Anamuah-Mensah, Director of the Centre for School and Community Science and Technology Studies (SACOST), University of Education, Winneba, Ghana for writing the 'Foreword' to this book. We thank George J. Sefa Dei's doctoral student, Yumiko Kawano, of the Ontario Institute for Studies in Education of the University of Toronto for the administrative and partial editorial work to get the volume to the publisher. Working across the Trans-Atlantic has not been easy but the process has been facilitated by the love of learning that Yumiko brought to the work. We also want to thank Sense Publishers for the many ways of taking up the challenge to publish a book on Africa which is governed not strictly by market considerations but by the intellectual justice and rewards that accrue from such undertakings. The editorial staffs at Sense Publishers have been helpful and encouraging throughout the entire process from the initial conception of the idea of the book to its final production. We are deeply indebted to our individual families who have always been the backbone of our academic and professional growth and careers over the years. Finally, we dedicate this book to the young learners of today who are helping to redefine the goals, purpose and objectives of education and the role science education can and does play in African development and human condition.

FOREWORD

"If you want development, you should provide relevant education". Education has come to be seen as the key to unlocking the potential of African countries in their struggle to pave a sound pathway for the socio-economic and political transformation of their citizenry. However, this attempt to use education and schooling as the driving force has and continues to pose numerous challenges to many governments. One of the areas required for development but which at the same time poses a great challenge is science education or what is occasionally referred to as science, technology and mathematics, education (STME). It is accepted that without a strong foundation in science education, a country's development can be dwarfed. Science education has been a source of concern and worry to many parents, policy makers, teachers, school administrators and students. For one thing, science is perceived to be a difficult and alien subject by a number of students who believe they are incapable of handling it. Community elders wonder why science education is not transforming their communities and helping them to solve their problems. So how do we [as educators] present science in ways that are easily discernible to young learners? How do we ensure that science education maintains its important place in school teachings so as to help communities find practical solutions to the many problems encountered as part of everyday living? In effect, how do we prioritize and teach science education in African schools? These are not questions with ready answers. They are sources of contentions even among educators. The science teacher like any other teacher and learner has tremendous responsibilities, the least of which is to understand what constitutes science and how to approach its study and application of the knowledge gained to serve society. As societies struggle with basic existence, increasingly the role of science education is seen as critical to human survival.

In fact today, not many would dispute the fact that education is critical to national development. Arguably, the central or most pertinent question has been what kind of education and how educators place science and technology in debates linking education and development. Africa presents us with an interesting case. We have ample evidence of science education that happens everyday in our homes and communities, which is often either ignored or not seen as 'science'. We are also still trying to overcome the legacies of entrenched past when colonial education did not always place the question of educational relevance at the front and centre of national debates. Colonial, and to some extent even post-colonial, education was and has been geared to serve not necessarily local needs but the interest of external markets. This situation arose from the abortion of Indigenous cognitive traditions as a result of the imposition of Western science, which failed to integrate those traditions into mainstream science. It is my considered view that only a broad view of science that integrates the accumulated knowledge, values and customs of the people will help provide a holistic development of societies. According to Amartya Sen (in his book, *Development as Freedom*), education should expand the freedom that people need to make development possible. The expansion of science to include local/traditional knowledge expands the freedom that is needed to make

development happen. The outcome will be the promotion of creativity, innovation and problem solving and the discouragement of the pedagogy of rote memorization and recall, which prevails in our schools. This book is therefore welcoming for its attention to science and particularly, the teaching of science education in Africa in ways fundamentally helpful to the cause of Africa and African peoples – that is, providing greater freedom to the people. Asabere-Ameyaw, Dei and Raheem have assembled a very helpful bunch of papers for intellectual debates and policy action that go beyond the continent. The critical discussion of the subject of science, including the adoption of a broad view of science that encompasses the social, biological, natural and/or physical domains is significant. The fact that the papers deal with diverse aspects of science and emerge from educators located in geographically diverse places, including operating in different academic fields of higher learning, is an asset. I am also impressed that the discussion avoids the usual strict dichotomy between local/traditional and Western science and rather makes a case for taking local/Indigenous knowledge seriously as a form of science education. What this entails is an evaluation of science along multiple perspectives and in pursuit of diverse educational agendas.

The editors ably worked with the contributions submitted to create three interesting and interrelated intellectual/discursive stances: First, is the argument that the teaching of conventional science must be rethought [and perhaps retooled] to fit with local contexts while at the same time maintaining the basic tenets of what science education is universally. For example, there is something worthwhile in teaching science, technology and mathematics in the African contexts. However, it is argued that we must broaden the contents of school science curriculum and also engage in multiple pedagogical and instructional strategies and practices to comprehensively educate the African learner. This is the only way we can make science education welcoming and relevant to students and for the subject of science not to be perceived as an alien field of study. This position identifies grounds of divergence as far as the contents of natural/physical/biological science education and that of social science education is concerned. Nonetheless, all the sciences share very basic principles, as well as key pedagogical and instructional strategies in that they are contextualized teachings pursued appropriately from where learners are situated. This also helps for inter-disciplinary challenges in educating the learner of today to be understood and pursued in ways that are mutually beneficial to the development of academic disciplines and subjects. The African learner must be able to saddle different disciplines and at least engage in academic and social conversations drawing upon the knowledge and strengths of inter-disciplinary analysis. As the divide of ‘social’ and ‘natural/hard’ sciences are made less visible the student is served best and can develop his/her potential to become a holistic learner. To this end, there are useful discussions in the book to help the African learner strive to be a more complete learner. After all, the successful learner today is one who is open to different ideas and is not closed-minded to disciplines other than his/her ‘own’.

Secondly, local/Indigenous knowledge is itself a form of science which must be taught in schools as part of an educational approach to broaden conventional

understanding of what is science. This position is relevant if we are to challenge colonial education that historically served to marginalize African peoples' ways of knowing, including their cultural norms and practices, technologies, arts, languages and literatures. Indigenous knowledge as science also presents us with an understanding of knowledge as a form of systematic coherent thought processes and ideas. In addition, it has its own fundamental principles and ideas like every knowledge system. These principles regulate human behaviour and action and also offer social explanations to complex human issues. Such knowledge has its own cultural logics. Indigenous knowledge has a content and form and processes of coming to know. As science, such knowledge is acquired through learning and posits a form of culturally contextualized reasoning that works with its unique claims of "objectivity', 'truth' and 'neutrality'. Such knowledge is not posited as binary to Western knowledge or thought as such. However, while claims of universal sharing of these ideas can be made, we must also acknowledge the important philosophical differences among diverse knowledge systems. As it is argued, Indigenous knowledge brings to bear a sense of the connections of people to their cultures, society and Mother Earth. This is important as it enables learners to relate their knowledge to solving problems in their communities.

Thirdly, following from the preceding argument, science education is presented broadly to include what the authors are calling 'science of the social' in their bid to provide holistic education. In this approach, science education is perceived to be expansive enough to include, for example, civic education and environmental education. Science is language, arts, politics, history and culture. A number of the papers take this stance concretely. This approach to science education is aimed at creating a more responsive education and making the learner well in tune with every aspect of their social existence. The argument being advanced is an attempt to move the discussion of science into a new terrain. It has relevance in the African contexts where local knowledge systems shun the atomization, particularity and insularity of knowledge and learning. We cannot understand the social without a connection with the natural, physical and metaphysical. For example, economics is an interrelation of politics, culture, language, arts, environment, etc. If the African learner is taught to value these interdependences and connections, it is possible their static, conventional and mythic view of science education can change. This requires an 'art of teaching science'.

Beyond the question of what is science is the how to teach of science that goes beyond providing the expert knowledge base to students. Effective science teaching requires that our schools are best equipped with the tools for delivering education. It may require a rethinking of the whole process of educational delivery [structures, processes and administration of education] so as to allow young learners to engage their local/home-based knowledge as a starting point to learning. While many schools and educators see the emphasis on science as crucial for development our institutions are often limited in their pursuit of science education for the lack of physical infrastructure and other logistics (laboratories, equipment, etc). We need not forget that Indigenous ways of delivering education are tested.

The apprenticeship mode of training, story telling, observation and repeated practice provides examples that can be used in science education.

Our schools and educators can help African students realize their academic dreams and life ambitions about science education. We must seriously engage the question of what type of education are we ready to provide the learner in our educational institutions so as to succeed in performing their responsibilities? Education should help us know ourselves, our past and histories, cultural and intellectual traditions in science, technology, development and all fields of scholarship. Education must be geared towards social transformation and not simply education for the sake of knowledge production. A transformative education helps young learners' ride interdisciplinary bridges to scholarship and intellectual thought. We must be willing to invest in the human resources available in our schools and nurture success. Of course, our students themselves also have a responsibility to improve upon their own learning. But for the purposes of the objective of this book the position that there is a need for multi-/inter-/trans-disciplinary approaches to course content and delivery of science education makes it imperative that we assist African learners to survive in the competitive global economy where education in the sciences is key. I am confident that the vision expressed in this book will be a powerful lever for engendering intense conversation on the merits and demerits of broadening the field of science to include social and cultural issues and to give recognition to local/traditional knowledge systems.

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INTRODUCTION

INTRODUCTION TO CONTEMPORARY ISSUES IN AFRICAN SCIENCE EDUCATION

INTRODUCTION

The purpose of this book is to contextualize Indigenous science and science education in the African context as a way of reconsidering/revising schooling and education. We define science broadly to include both the science of the natural/physical/biological and the 'science of the social'. By 'science of the social' we mean science defined broadly to include the nexus of the physical, social, natural and biological terrains of knowledge which can be taken up equally as methodological tools and ways of knowing providing a more comprehensive understanding of our worlds. Perhaps African education continues to be a subject of intense intellectual discussion. There are passionate arguments that schooling and education in Africa need to prepare the Indigenous learner to understand his/her own social condition and what it means for critical education to help search for effective, home-grown solutions to our own problems (see Keane, 2008; Le Grange, 2004). Science and technology, while generally admitted as a path for national development, is still mired in contentions about school curriculum content and delivery (see Le Grange, 2007; Dalvit, Murray, & Terzoli, 2008; Ezeifa, 2003). It has been pointed out that African science and technology is steeped in Westocentric thinking, rather than making use of available resource knowledge within local environments (see Jegede, 1989, 1992, 2004; Jegede & Fraser, 1990; Solomon & Aikenhead, 2004). Despite the hard work of a number of educators and administrators, schools in Africa continue to suffer from a lack of adequate resources [staff, physical, infrastructural] and development. Young learners either shy away from applying school knowledge, or are not prepared enough to apply what they have learned in their classrooms to everyday community problem solving. Even when the link between education and development is readily asserted, it is not often theorized and/or operationalized in ways that make sense to local conditions and challenges. In effect, African education is geared towards a Western expert-led economy and a tendency to offer a techno-fix approach to educational problems. Accordingly, how can we [as educators, researchers, students, policy makers, etc.] collectively and effectively diagnose the malaise of African education in order to think through and offer genuine educational options to young learners?

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Among the ways to counter-vision contemporary African education, one can point to how we promote Indigenous science education to improve/enhance African science and technology development in general. There has been a long-standing push to reexamine local cultural resource knowings in order to appreciate and understand the nature, content and context of Indigenous knowledge science as a foundation to promote African science and technology studies in general. We believe these interests and concerns are not mutually exclusive of each other but as a matter of fact interwoven and interdependent. The primary focus in this collection has been to understand the influence of science, spirituality, the environment and civic education in our bid to fashion a more creative way of enhancing African science education. We have reconceptualized our understanding of the broader questions of African culture, identity, history and politics and their implications or re-visioning African education for contemporary learners. Consequently, the breadth of coverage of the collection reflects papers in science, Indigeneity, identity and knowledge production and the possibilities of creating a truly African-centred education. It is our hope that such extensive coverage will engage and excite our readers, as we take on the path of what we are termed 'African educational recovery'.

The purpose of this manuscript is not to rehash a debate about the 'Eurocentricity of Western scientific knowledge' and the positing of 'Eurocentric science' as the only science worthy of engagement. It is nonetheless important to caution against constructing binary understandings of Indigenous/local science and knowledges and Western 'scientific' knowledge. After all, Western scientific knowledge is itself a form of local knowledge, born out of a particular social and historical context. Engaging science in a more global context will bring to the fore critical questions of how we create spaces for the study of Indigenous science knowledge in our schools. How is Indigenous science to be read, understood and theorized? And, how do educators gather/collect and interpret Indigenous science knowledges for the purposes of teaching young learners?

Educators have recognized that science, particularly the 'hard' sciences [biological/physical/natural], is an area that most students experience difficulty with. A critical discussion of Indigenous science education knowledge must focus on the construction of knowledge, access to knowledge, the transfer of knowledge and the application of such as part of multiple ways of knowing. We hope to address the trivialization and devaluation of traditional sciences and the richness of local knowledges in the academy. A major preoccupation as we discuss traditional science knowledge in the academy is to address the trivialization/devaluation of local knowledges. Formal school systems have downplayed Indigenous science in science education with the resulting effect that we have local/Indigenous and even Western-educated scholars not schooled in the socio-cultural and philosophical paradigms of their own communities. Science education is critical to national development and yet there is a gap in our understanding of an Indigenous consciousness to cultivate such local knowledges, which can contribute to the search for home-grown solutions to local problems and challenges. Science education must be rooted in understanding local ecosystems and the particular

socio-cultural and political milieu of producing 'scientific' knowledge. Local cultural knowledges herald the spiritual and cultural foundations upon which the survival of local communities rest. Validating Indigenous knowledge can thus only contribute to the search for "home grown Indigenous perspectives steeped in culture-specific paradigms" (Yankah, 2004, p. 26).

Many researchers and academics alike have argued Indigenous knowledges emphasize a physical and metaphysical interdependence (Odhiambo, 1972; Ermine, 1995; Semali & Kincheloe, 1999; Battiste & Henderson, 2000; Castellano, 2000, see also recent pieces in Denzin, Lincoln & Smith, 2008; Dei, 2011). As a form of epistemology, Indigenous science knowledge also signals a society, culture and nature nexus. Like every form of knowledge, Indigenous science knowledge has its own ontological, conceptual/philosophical, methodological and axiological groundings. As a science, philosophy and intellectual practice Indigenous knowledge acknowledges one's existence as not conscripted and scripted by simply a colonial and colonizing experience. The knowledge that is on the margins speaks to local intellectual agency of a people to define their own history, identities, destinies and the will to create their own futures. In effect, an Indigenous science knowledge system would comprise an understanding of the successful ways by which a people deals with their environments and surroundings to solve everyday problems and challenges.

In this collection, we pay particular attention to Indigenous science because we see a link between how educators can effectively promote science teaching in schools and the particular working understandings of the way in which science can be articulated by African educators. We have outlined a pedagogy and instruction of science education that is holistic in its engagement of bodies of knowledge. Since Indigenous science is also about Indigenous/local knowledge, the promotion of African science education predicated on the ability of educators and schools to offer a space for the promotion of Indigenous knowledge as a valid way of knowing. For example, we believe we can demystify the teachings of science once it is grounded in local knowledge and surrounding knowledge for learners to know that such knowledge is not after all alien to their cosmological knowings. The interconnections of science, culture and development indicate the important place of science education in our schools. The call for emphasis on science and technology education in our schools can also assist in African development if the teaching of science is pursued in a way that connects with local learners and their social, physical and cultural milieus. Thus, the teachings of science have to integrate our Indigenous ways of knowing with so-called Western science knowledge given the multiple and collective dimensions of knowledge (see also Solomon & Aikenhead, 2004).

Throughout this collection we have taken the liberty of providing a very liberal definition of 'science' in an intellectual and political project to tackle the dominant ways in which the term has been engaged. To reiterate, our project is not to be seen as a mere extension of dominant paradigms; but as one that challenges, complicates and subverts such dominant ways of knowing. To this end, we also note that in a collection such as this manuscript it can raise a host of pertinent issues under the

broad terrain of science education for discursive emphasis. At this juncture, we want to purposively and briefly highlight three specific areas: The complex issue of spiritualism and science; the relevance of environmental science education; and, how we can promote science as part of civic and peace education.

THE COMPLEX ISSUE OF SPIRITUALISM AND INDIGENOUS SCIENCE

Spirituality is not organized with a particular religion nor is it affiliated to particular faiths. Instead, spirituality is a way of life, a reading of the world that grounds the understanding of the self, personhood and the relations on the inner environments to outer spaces/environments and cosmologies. It is an understanding of the connections of the socio-cultural and physical universe; a communion of the material, physical and metaphysical worlds. It is not about an ascription of higher order, but rather an understanding of the existence of social forces beyond the ability and capacities of the human senses to easily comprehend the communion of social and metaphysical realities. Many of us acknowledge and respect our spiritual identities as part of who we are as individuals, a people and a collective. Spirituality is very central to the functioning and organization of Indigenous cultures. Through spiritualism we come to understand local peoples' ways of life, histories and system of belief in relation to their worlds. Many Indigenous communities attribute spiritual meanings to everyday life. For example, different deities have their special attributes as related to humans and there are social functions, powers and the cultural significance accorded to the Universe. Through everyday social activity, local peoples seek to reclaim their Indigenous spiritualities, knowledge systems, social, cultural and economic and resources. Spiritual practice in everyday life has also become a means and a process of recuperating, resisting and healing from the damage caused by colonialism when people move to rebuild healthy, independent and sustainable societies.

We take the position that it is through the mutual and critical interrogation of ideas, concepts, principles, symbols, cultural and social values that is the foundation of knowledge have been and can be truly established. Indigenous science emphasizes a physical and metaphysical interdependence. As a form of epistemology, Indigenous science also signals a society, culture and nature nexus. Like other forms of knowledge, every body of knowledge, Indigenous science has its own ontological, conceptual/philosophical, methodological and axiological groundings.

We answer the question by taking the following discursive positions. There is a place for spiritual knowings in Indigenous science and the teaching of such knowledge in schools (see Solomon Belay's paper in this collection). Consequently, the issue then is how we work with Indigenous spiritual epistemologies that assert among many things that spiritual ontology is about the nature of social reality and that what accounts for reality and the essence of being which is essentially a spiritual existence. We believe a spiritual ontology and spiritual teachings shape culture and what is science. The ontology of Indigenous science works with the idea that the Universe is basically a spiritual universe and Indigenous spiritual

ontologies express the essence of the relationship of the individual to society and nature. Most things in the natural world are imbued with spirits. Humans do not stand apart and neither are we above the natural world. We are part of the natural world. Meaningful social existence is by establishing communion with the 'spiritual' world (e.g., through the veneration of ancestors). In fact, within African systems of thought, ancestor/ancestress worship is based on two related notions, (a) life after death and (b) a continuity or linkage between the world of the living and that of the dead. This system of thought and belief process guides and regulates social conduct. It respects an ordered way of knowing with its own ontology and epistemological basis

Epistemology is more than a body of knowledge. It is a way of understanding social reality and explaining the guiding principles of social action. Within Indigenous epistemologies, certain contested claims are made; for example, the idea that spiritual identity is a way of knowing; and knowledge production is a connection to the body, mind and soul. We cannot privilege body of matter/mind and soul and vice versa. It is asserted that all knowledge is accumulated knowledge, based on observing and experiencing the social and natural worlds and thus every way of knowing is subjective and based in part on experiential knowledge. Social learning, it is argued, has to be personalized in order to develop the intuitive and analytical aspects of the human mind. To understand one's social reality, is to have a holistic view of society. The world is about inter-connections and inter-relations. In effect, we cannot separate politics from economics, culture, religion, cosmology, family and kinship (see also Dei, 1993, 1996). Spiritual epistemologies connect place, spirit and body (see also Meyer, 2008). The spiritual is embodied and every life form exists in paired relationships and interconnections. What this means is that there are no definitive distinctions in life (as in young/old, man/woman, individual/communal, mind/body, personal/political and the social/ natural).

THE QUESTION OF ENVIRONMENTAL SCIENCE EDUCATION

Studies of African Indigenous knowledge systems attest to how the physical environment has been an important source of knowledge about herbal pharmacology and herbatology, Indigenous farming technologies, traditional arts and crafts, including folkloric productions, knowledge of climatic changes and patterns, as well as local soil and vegetation classification systems. The preservation of the African physical environment as an important source of local cultural knowledge is critical if educators revise science education in African schools. Critical science teaching in schools must include and help young learners to engage environmental science knowledge (see also the paper by Mawuadem Amedeker and Thomas Young in this collection). There is a need for environmental science education that stresses the interdependence of society, culture and nature and the necessity for living communities to be in 'harmony' with their physical environments for collective survival. For example, science education must teach about local traditions of sustainable environmental resource use and particular cosmological

beliefs systems and worldviews/worldsenses that herald the sanctity of land and physical environment. It is such a knowledge base that has helped local communities sustain their environments through time. Unfortunately, today's market forces and, particularly, the forces of globalization are fast encroaching upon and abusing the sanctity of land and physical resources held in local communities. Local environments have been under assault as people seek out daily material existence well beyond their means. Local peoples have continually been told to conserve their physical environmental resource only for multinational corporations to turn around and abuse such environments. In such cases, local peoples have not enjoyed the benefits of their restraint. We need critical education that protects and makes for sustainable environmental resource in order to preserve the physical environment for current generations and the generations to come. Environmental science education is more than impacting knowledge about the working of the biosphere. Environmental science education is about taking responsibility. It is teaching about how local communities can maintain a fitting balance between their needs and sustain resources for use through time. It is about teaching to battle the ills of individual, social and corporate greed that have and continue to wreak untold havoc on physical environments and racialized communities. It is about teaching ways communities are addressing and can redress ongoing environmental degradation and the ecological imbalance of the environments. Science can contribute to the task of sustaining local physical environments through knowledge about appropriate technology use. We know how science and technology can contribute to environmental degradation when they are not conducive to local environments. The development of science and technology in Africa has to take into account the impact of such knowledge on local environments.

Apart from been viewed as a productive resource, the environment has been a site of knowledge. Environmental science education in school must therefore examine the power and asymmetrical power relations that have been structured around the environment and human use and how ecological spaces have been created, owned and territorially defended. The environment also raises key questions of ethnic/race, gender and class relations in terms of how such identities inform our everyday relation to local environments and the particular knowledge we develop and work with. Particular conceptions of humanity have become dominant discourses that express our collective destiny in maintaining environments without acknowledging our differential responsibilities and culpabilities in degrading environments and the problem of modernity (e.g., globalism and forces of globalization) that continue to create environmental disasters (e.g., polluting gas emissions, climatic changes and other human-made environmental disasters). Environmental science education would teach about the impact of development on local developments and the relevance of local science knowledge for ordinary people to be aware and combat environmental degradation. Let us take for example, the building of the Akosombo dam, an anthropogenic hydroelectric project situated on the Volta Lake in Ghana. This project supposedly sought the interest of local peoples through offering jobs such as fishing, farming and

transformation. However, as amplified by Gyu-Boake (2001), the Akosombo dam has been connected to particular water-borne diseases, increased weeds in the lake, all of which harm fishing as a way of life. The effects of the dam has also increased drought due to decreased rainfall in the forest and savannah regions of West Africa. More so, changes in the dam have also led to increase in atmospheric temperature due to high evaporation, while local peoples have also noted changes in wind speed on and around the lake. Gyu-Boake (2001) further speaks about the social problems resulting from the Akosombo project due to resettlement and the loss of Indigenous land and cultural practices. Environmental science education will have to sustain lives of local peoples in ways that work with understandings of the connections of society, culture and nature (see also Dei, 2010).

SCIENCE AS CIVIC AND PEACE EDUCATION

Science education must also promote civic and peace education (see Wangui Mburu's paper in the collection). For example, Indigenous science knowledge and teachings relating to African proverbs highlight youth moral and character development, the importance of developing a sense of civic responsibility, community building, citizenship and schooling as a community (see George Dei's paper in this volume). Learners in our schools, colleges and universities come from diverse and different economic, regional, linguistic, cultural, ethnic, religious and linguistic backgrounds. African education in a post-colonial context cannot sweep such differences and the diversities in the student population under the carpet. While post-colonial education must promote national integration and social cohesion, such goals cannot be achieved by simply sweeping away social differences. These differences can be tapped into as sites of strength and education by science educators to enhance learning for the entire student population. Science education can contribute to the cause of civic education teaching about collectivity among young learners moral and community values that cherish mutual interdependence and responsibilities to self, family, community, nation and global citizenship. In many pluralistic contexts, multicultural education has promoted cultural diversity as an intrinsic and valuable component of the social, political and moral order. A diverse schooling population is valued on the basis of a common humanity with a collective future assured by goodwill on the part of all. The contributions of different cultures and ethnicities to national well-being and destiny are acknowledged (see Dei, Asgharzadeh, Eblaghie-Bahador, & Shahjahan, 2006). Science education can contribute to this goal of education by emphasizing the varied contributions of our different groups to science and culture knowledge. Effective science education will include an analyis of the processes of teaching, learning and administration of science in schools and the ways in which these processes combine to produce differential interests and learning outcomes among young learners. Teaching about science as civic education for peace is bringing into the schooling dialogue discussions around identity, citizenship and belonging, as well as pointing to how citizenship, community building, claims of ethnic, gender, class, religious identities, history, politics and knowledge all converge to

produce and inform the contemporary learner. Science as civic education is about making claims to self and collective worth that include a connection to everyone around us (including social communities and our natural environments). A critical approach to science education ontology would herald the interface for society, culture and nature and point to a spiritual sense of self and place. Science as civic education for peace is bound by connections of inter-dependency and inclusion (see also Asabere-Ameyaw & Adzahlie-Mensah's paper in this collection). Science for peace education is teaching the social as science. Science as civic education for peace must speak of the intersubjective nature of human interest. Such education must be cognizant of the different ways and methods through which we come to know and understand social relations. It calls for moving beyond armchair theorising to respond to local problems with colonial historic specificities through the Indigene. Notably, the relations with the Indigene and the intersubjective ontology of the social are incommensurable and not categorised through a collective valid list of rules, but more so through the lived experiences embedded within the African commune. Science as civic education is about dialogue through critical consciousness as it cogitates itself through the particularity of the African social as historically developed. In rethinking African science as civic education, the knowing self cannot assert itself as authentic, as the lone expert of knowledge. Instead the self itself is rooted in an ontology through transgressive pedagogies in order to speak through a certain primacy of the African 'social'. Educating about African science as civic education is guided by the principle that the conditions of knowledge are embedded within the social practices of local African communities and moreover, these practices have been ontologically oriented through oral histories, folklore and proverbs. Our position is one where science as civic education is not about substituting conventional classifications of science, with African science as civic education, but instead about troubling the hegemonic hold underscoring the multiple ways of interpreting particular epistemologies through cultural difference as science.

CHAPTER OUTLINES

The beginning chapters of this book set out the nature and context of the problem of science education that African schooling and education has to contend with. Subsequent chapters offer inclusive and counter visions of science education that can be embraced in order to provide and ensure that the African learner receives a more holistic and inclusive understanding of science education in general.

Our beginning chapter, "The question of Indigenous science and science education" is basically an examination of some of the relatively recent literature addressing the question of instruction, pedagogy and pursuit of science education globally and specifically in the African context. While we broach and appreciate the complexity and depth of the subject matter and attempt to understand the various scholarly methodological approaches to research studies on the topic of teaching science education, we highlight in particular the significance of the nexus of the society, culture and nature in understanding and revising science education.

We engage a discussion of the complex issue of spiritualism and science education to understand its place and the challenges posed for educating young learners.

In her piece, "Investigating the school science project in Africa" Wanja Gitari acknowledges the role school science plays in the improvement of social welfare and development in general. The author contends that despite such understanding, the promotion of science education as one of the key means for social welfare has so far not contributed to addressing developmental challenges of Africa. The author adds voice to the many scholars pointing to the lack of an endogenous culture of science in Africa; notwithstanding the fact that education and community development sectors, as well as "scientifically based organizations" have championed the development of a culture of science. Gitari reviews the existing literature to offer an analysis of the successes and difficulties of the ongoing attempts at science education. Among the questions raised are: "How has the science project been structured and implemented? What are some of the successes and difficulties with … [the conventional approach for implementing science teachings]? And what is the outcome of the science project and implications for the future of school science in Africa?" The focus of the author's critical examination is science and technology policy and practice, the conventional use of school science to solve problems in everyday life and the social economic welfare and community development. In the end, the paper identifies the roles, opportunities and limitations afforded by school science in transforming local people's everyday lives through institutions such as ministries of education, ministries of science and technology, schools, international (development) organizations and local non-governmental organizations.

In their review of some of the existing scholarship on the effect of language proficiency on science concept learning, Akwasi Asabere-Ameyaw and Jonathan Samari Ayelsoma's paper "Language proficiency and science learning" presents readers with some interesting perspectives on the 'language of science'. In pointing to the links between science concept learning and second language learning, the authors also allude to the challenges of language proficiency in conventional science education. It is explained that there is an established way of talking about science, that in schools young learners are encouraged to express their ideas and to question evidence in investigations of public science issues, usually through established conventional modes and medium of communication. Accordingly, a binary notion of how science is learned often presents challenges for students for whom English is a second language. The authors point out that a key determinant to science achievement is significant research documentation of proficiency in language instruction. For a young learner to understand scientific concepts and communicate effectively using such science concepts, she or he must first understand the language in which the concepts are being presented. This paper has implications for re-visioning African schooling and education in science. As the authors note "the exclusive use of foreign language for science instruction could be detrimental to the acquisition of scientific concepts among Indigenous communities" and lead to disaffection and disengagement from school. Therefore,

Indigenizing the school curriculum can strengthen young learners in the acquisition of scientific knowledge and skills.

Richard Akpanglo-Nartey, Akwasi Asabere-Ameyaw, George J. Sefa Dei and Kodjo Donkor Taale's paper, "Children's Indigenous ideas and the learning of conventional science" examines young learners' Indigenous ideas and the learning and acquisition of conventional science. The paper is informed by the findings of a specific case study that sought to know and understand some of the ideas children had on scientific processes and concepts prior to learning of school science. Through the administration of a questionnaire and conduct of interviews with a sample of Ghanaian high school students and science teachers, the authors point to the prior knowledge about science that young learners have about conventional science is largely informed by their own observations, customs and beliefs of the society and their religion. Though most of these prior conceptions were at variance with conventional school science, science teachers found a way to work such knowledge pointing to the place of conflicting ideas in science education. Unfortunately, school curriculum materials often do not integrate or work with learners' Indigenous ideas about science. It is argued that a transformed curriculum that is able to work with learners' Indigenous ideas, placing them on the table for discussion in science education, holds promise for radical science teaching in our schools.

John Enimah, Kodjo Donkor Taale and Kolawole Raheem in their study "Science student teachers' attitude towards improvisation', note that the shortage of science instructional materials in pre-university institutions in Nigeria has been a topical issue for quite some time now. The persistence of the problem prompted their study which targeted levels 200 and 300 students in the education department of a tertiary institution in Katsina State, Nigeria. A total of 150 randomly selected students were requested to complete a questionnaire containing 16 Likert-type attitude items on improvisation. Data from 129 usable questionnaires were then analyzed. Among study findings, it was revealed the students had a positive attitude towards improvisation, while the teachers (among the respondents) had a higher positive attitude than the non-teachers. Notwithstanding, the overall positive attitude of the students towards improvisation, it was found that 12 of them had negative attitudes towards improvisation. This interesting finding appears to indicate that in spite of the students' aspiration to be science teachers after completing their programmes, some of them had not acquired the dispositions required of professional science teachers. One can only surmise that the nature of the problem has equally to do with how science has conventionally been taught and understood in African schooling context.

Dorian Barrow in his paper, "Beliefs about the nature of science held by African teachers in the Caribbean Diaspora" argues that theory, methods and knowledge gained from years of study of Indigenous science and practices apply to the understanding and improvement of teacher quality and ultimately, student achievement. With these applications, science education research has the strong potential to make more effective and systematic contributions to the improvement of science teaching in culturally diverse school settings. This potential can be

realized by linking the scientific study of teacher beliefs to teachers' classroom behaviors and student achievement. This chapter advances a perspective on teacher beliefs about the nature of science and science education and their interactions with teacher classroom behavior in secondary schools in Tobago. The article (1) offers a view of the role of socio-cultural context in the formulation of teachers views of the nature of science and science education; (2) show the role of metaphors as a way of thinking and a guide to action; and (3) discusses the empirical basis upon which useful cross-cultural comparative analyses and extrapolations may be made. The article synthesizes research from the fields of Indigenous studies and science education and closes with recommendations for developmentally oriented research on teacher quality in cross-cultural contexts.

Francis Ahia and Fredua Kwarteng's chapter "Teaching and learning of mathematics/Ye Asisi Yen" [literal meaning 'We have been shortchanged'] offers a poignant and refreshing critique of traditional methods of science teaching using the study of conventional mathematics as a case in point. The paper begins by critiquing the (standard) pedagogy of mathematics teaching and learning in Ghana's schools, with its emphasis on 'facts' with no or little attention paid to context and disregard for the student life-world. This paper has implications for educating young African learners, arguing that standard mathematics and science pedagogies lead to memorization, an over reliance on formulas and what is termed "parroting of knowledge". The authors point out that 'meaningful' mathematical skills and knowledge is acquired "when attention is given to concept development, knowledge construction and their application in context in the teaching and learning of mathematics." Accordingly, mathematics teaching and learning becomes a preparation for life, rather than as a means of passing tests. In conclusion, the paper spells out the broader implications for science education in Africa.

George J. Sefa Dei's paper, "Culture, identity and science in African education: The relevance of local cultural resource knowledge" seeks to challenge the coloniality of 'science' and 'scientism' and the way dominant science as a body of knowledge has served to delegitimize certain Indigenous and cultural ways of knowing. Using a Ghanaian [and to a limited extent Nigerian] studies of Indigenous cultural teachings of proverbs, the author makes the case that the education in Africa should first be about helping young learners understand and respect the self and group, identities and cultures and the community values of discipline and social responsibility. Dei argues that there are cultural teachings that constitute part of the knowledge base of 'Indigenous science'. The paper helps to reposition science not as "a methodological tool, but rather as a frame of cultural reference, a way to raise broader existential questions about self, group, culture, history and identity and how we make sense of the connections of people to their social and natural worlds". Such thinking primarily connects science to culture, values and ideas about human existence and social relations, as well as helps create a 'worldsense' of interconnections of self, group and community.

Ethiopia is a country, as is the African continent, that is, "much impregnated with innumerable spiritual and cultural heritage." Solomon Belay in his manuscript

"Ethiopia survives: Reintegrating our spirituality and culture into our own science" argues that any viable educational options [including science education], must take into account students' spiritual and cultural values. Given that the process of knowledge construction is influenced by experience, prior knowledge, values, beliefs, as well as socio-cultural factors of community life, the author argues that improving science education in Ethiopia requires an examination of the spiritual and cultural practices in which education is generally contextualized. Using an ethnographic study based on interviews, observations and focus group discussions, the paper highlights specific spiritual and cultural values of Ethiopian communities that can be engaged in science education. It is noted that science has been an integral part of Ethiopian spirituality and culture and a science education that resuscitates Indigenous culture can facilitate students' learning of science.

Wangui Mburu's paper "Indigenous conceptions of civic education" explores the educational implications of Indigenous knowledge for promoting science and civic education in African contexts. The author argues that in the face of rising violence in many communities, a growing number of educators have viewed civic education as possessing pedagogic and instructional relevance for the promotion social cohesion and democratic practices that enhance peaceful coexistence. Mburu argues that in many Indigenous cultures, civic education has been pursued primarily as a way to bring about social harmony among diverse cultures and peoples and also, to ensure mutual coexistence with nature. It is opined that Indigenous conceptions of civic education is good for humanity in general and that schools in Africa, rather than mimicking Westocentric conceptions of civic education, could return to their local cultural resource knowledge base and understand the principles and ideas that promote genuine civic education. Using case material from her doctoral dissertation research in Kenya, Mburu shows the relevance of civic education in Kenyan schools as part of a new wave of critical science education.

Akwasi Asabere-Ameyaw and Vincent Adzahlie-Mensah's article, "Achieving the culture of limited aggression – The role of higher education institutions", undertakes the debate on African science education further through a socio-cultural and political lens/context. This paper recognizes that educational reform initiatives are not possible without peace. The necessary conditions for the pursuit of education must be achieved before one can pursue genuine educational initiatives in Africa. The paper highlights the nature and extent of the deadly conflicts all over the globe in the twentyfirst century. It cites the "increase in terrorists' activities, the greed in exploiting and use of natural resources and degradation of our environment are resulting into preventable conflicts and deaths" and asks: what can be done to deal with these problems and lessen the conflicts and the terrible consequences? It is argued that perhaps an answer lies in establishing Peace Education in our schools and higher institutions of learning. Through a 'Culture of Peace Education', it is hoped that educators can contribute to "resolve conflicts without resorting to war or using the "survival of the fittest" approach. The paper advances the principles behind peace education and how it shapes the role higher education plays in the development of peace culture. There is a focus on the World

Education Forum in 2000 that led to two major frameworks relevant to the development of peace education programme: first, the establishment of the International Network for Education in Emergencies (INEE), which was formed to coordinate the provision of education and how it can be used for conflict prevention, both as humanitarian response and for post-conflict reconstruction; and, second the Dakar Framework for Action which called for the promotion of educational programmes in ways that promote mutual understanding, peace and tolerance to prevent violence and conflict. It is argued that peace education curriculum of education in higher institutions should consider the increasing migration, the effects of globalization and the advancement of information and communication technologies which have made people today increasingly mobile.

The chapter by Mawuadem Amedeker and Thomas Young on "Environmental hazard communication: Revisiting the Indigenous methods to meet the challenges in Ghana," notes that environmental awareness level of rural and urban dwellers in Ghana has been called into question on a number of occasions. The turning point in Ghana's environmental concerns came when the Environmental Protection Council, which later became the Environmental Protection Agency (EPA) was set up on 23 January 1974 to protect and improve the environment in Ghana. Since then, Ghana has initialized a number of international agreements for proper environmental management and also signed a number of environmental protocols (e.g., the Kyoto Protocol, signed on 30 May 2003 under the United Nations Framework Convention on Climate Change, aimed at halting global warming). The authors argue that in the Southern world today our institutional frameworks for environmental impact assessment are modeled on those obtainable in the West. The motivating factor being that most environmental impact assessment policies emanate from and are funded by the Western world. Unfortunately, these international environmental prescriptions often ignore potential contributions from Indigenous knowledge, hence their failures in African countries. The paper outlines ways in which students of environmental studies can contribute to Indigenous science and environmental knowledge. The authors show how parents, families, elders and the local environment are cultural custodians of invaluable sources of environmental issues. The authors make a case for integrating Indigenous knowledge about local sustainable environmental use into the environmental discourse so as to effectively deal with pressing contemporary environmental problems and challenges

REFERENCES

Battiste, M., & Henderson, J. Y. (2000). What is indigenous knowledge? In M. Battiste & J. Y. Henderson (Eds.), *Protecting indigenous knowledge and heritage* (pp. 35–56). Saskatoon: Purich.

Castellano, M. B. 2000. Updating aboriginal traditions of knowledge. In G. J. S. Dei, D. Goldin Rosenberg, & B. Hall (Eds.), *Indigenous knowledges in global contexts* (pp. 21–36). Toronto: University of Toronto Press.

Dalvit, L., Murray, S., & Terzoli, A. (2008). The role of indigenous konwledge in computer education in Africa. In M. Kendall & B. Samways (Eds.), Learning to live in the knowledge society (pp. 287–294). Boston: Springer.

Dei, G. J. S. (1993). Indigenous African knowledge systems. *Tropical Geography, 14*(1), 28–41.

Dei, G. J. S. (1996). Anti-racism education: Theory and practice. Halifax: Fernwood.
Dei, G. J. S. (2010). The environment, climate change, ecological sustainability and antiracist education. In F. Kagawa & D. Selby (Eds.), *Education and climate change: Living and learning in interesting times* (pp. 89–105). New York: Routledge.
Dei, G. J. S. (Ed.). (2011). Indigenous philosophies and critical education. New York: Peter Lang.
Dei, G. J. S., Asgharzadeh, A., Eblaghie-Bahador, S., & Shahjahan, R. (2006). *Schooling and difference in Africa: Democratic challenges in a contemporary context*. Toronto: University of Toronto Press.
Denzin, N., Lincoln, Y., & Smith, L. T. (Eds.). (2008). *Handbook of critical and indigenous methodologies*. Los Angeles: Sage.
Ermine, W. (1995). Aboriginal epistemology. In M. Battiste & J. Barman (Eds.), *First nations education in Canada: The circle unfolds* (pp. 101–112). Vancouver: UBC Press.
Ezeife, A. N. (2003). Using the environment in mathematics and science teaching: An African and aboriginal perspective. *International Review of Education, 49*(2–4), 319–342.
Gyau-Boakye, P. (2001). Environmental impacts of the Akosombo Dam and the effects of climate change on the lake levels. *Environment, Development and Sustainability, 3*, 17–29.
Jegede, O. (1989). Towards a philosophical basis for science education of the 1990s: An African view point. In D. Herget (Ed.), *The history and philosophy of science in science teaching* (pp. 185–198). Tallahassee: Florida State University.
Jegede, O. (1994). African cultural perspectives and the teaching of science. In J. Solomon & G. Aikennhead (Eds.), *STS education: International perspectives on reform* (pp. 120–130). New York: Teachers College Press.
Jegede, O., & Fraser, B. (1990). The effects of instruction on science students: Sociocultural attitudes and achievement. *Singapore Journal of Education, 1*(1), 12–18.
Keane, M. (2008). Science education and worldview. *Cultural Study of Science Education, 3*, 587–621.
Le Grange, L. (2004). Western science and indigenous knowledge: Competing perspectives or complementary frameworks? *South African Journal of Higher Education, 18*(3), 82–91.
Le Grange, L. (2007). Integrating western and indigenous knowledge systems: The basis for effective science education in South Africa? *International Review of Education, 53*, 577–591.
Meyer, M. A. (2008). Indigenous and authentic: Hawaiian epistemology and the triangulation of meaning. In N. Denzin, Y. Lincoln, & L. T. Smith (Eds.), *Handbook of critical and indigenous methodologies* (pp. 211–216). Los Angeles: Sage Publications.
Odhiambo, T. R. (1972). Understanding of science: The impact of the African view of nature. In P. G. S. Gilbert & M. N. Lovegrove (Eds.), *Science education in Africa* (pp. 39–46). London: Leinemann.
Semali, L., & Kincheloe, J. (Eds.). (1999). *What is indigenous knowledge? Voices from the academy*. New York: Falmer Press.
Solomon, J., & Aikennhead, G. (Eds.). (1994). *STS education: International perspectives on reform*. New York: Teachers College Press.
Yankah, K. (2004). *Globalization and the African scholar*. Legon: Faculty of Arts, University of Ghana.

AKWASI ASABERE-AMEYAW, GEORGE J. SEFA DEI
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THE QUESTION OF INDIGENOUS SCIENCE AND SCIENCE EDUCATION

A LOOK AT THE CURRENT LITERATURE

INTRODUCTION

The possibilities of Indigenous science and the incorporation into school science and technology education are tremendous. We assert that educators can further the cause of schooling and education by helping the youth to engage the self, group and community in the responsibilities of national development, and together with our diverse communities of learners, develop an in-depth understanding of what it is we are teaching, learning and why. So we ask what is educating about science? This is not an easy question. As already noted, this is in part because the term 'science' itself as has been argued is a loaded term with lots of cultural baggage. The question is also contentious for a people whose Indigenous/cultural knowledge base has constantly been devalued over centuries. In this paper, we look at some of the relatively recent work in the area of pedagogy and instruction of science education and what they point to in terms of a call for a multicentric perspective on the education of science through the integration of local cultural knowledge. The examination of the existing literature, while not exhaustive by any account, suggests to us that the questions of Indigenous culture, identity, history and politics can implicate a radical revisioning of science for contemporary learners. It also suggests that even from a methodological position there are broader philosophical and theoretical implications of our understanding of science, science education and Indigenous science. The challenge to create space for the study of Indigenous science in our schools/academies will require that we understand and examine our current pedagogical and instructional modes.

THE PEDAGOGY AND INSTRUCTION OF SCIENCE EDUCATION IN SCHOOLS

In looking at some of the most current works pertaining to science education, a number of different pedagogical suggestions have been identified but the overall theme remains the teaching and reinforcement of the Western scientific method as the only method of knowledge production. Recommendations from authors have stressed an increase of technology used within and outside the classroom and the teaching of "scientific tools" including the ways to make and defend an argument and how to better codify the world. Many of these recommendations have taken for granted the scientific method while the others attempted to expand current

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pedagogies to better address it. Overall, it is apparent in these readings that there is one way to do science and that students are not presented with any other methods of knowledge production. Buss (2010) explains that many preservice elementary teachers exhibit concerns regarding the teaching of math and science. His study aims to "examine the initial efficacy of preservice teachers for teaching science and mathematics and compare their efficacy for teaching these areas with other elementary school content areas" (p. 290). In his study, Buss (2010) operationalizes efficacy to refer to "the level of competency an individual expects to attain when teaching elementary content area material … efficacy beliefs may vary as a function of the personal experiences an individual had in a particular content area" (p. 291). He found that preservice teachers' efficacy scores were lower for math and science than other areas. Possible reasons for the lower efficacy scores in science and math by these teachers include doubts of their own abilities in these subject areas. In order to increase efficacy ratings, Buss (2010) proposes two procedures to improve teachers' efficacy: witnessing teachers deliver efficient lectures and taking more "effective models of science methods courses and mathematics courses" (p. 295). Finally, a number of questions are asked including "would individuals … who have low efficacy beliefs for teaching science spend less time teaching it? Would they engage in less planning time? Would they deliver instruction less effectively? Would they expend less energy in the science teaching situation? (Buss, 2010, p. 295). The object of course is to warn the reader of the possible ineffective practices of science education and the effects on the students who do not receive quality schooling. While these questions are important, this volume seeks to expand the concept of science education in a manner that engages with many methods of conducting science. After all, science education, if taught in a manner that engages the knowledges and methods of knowledge production of the community may become an easier task for the student as well as the educator. Thus, questions relating to this reading may be: how can the methodologies and pedagogies of Indigenous science help teachers feel more comfortable in teaching science? How can the teaching of a subject that inherently engages diverse learners in the practice of science help a student feel more confident and more engaged?

Efficient teaching may also be a result of finding new methods of engaging with the material. Hong and Kang (2010) insist on the perceived need to foster and encourage creativity in science students. The authors argue that science is "ultimately a creative endeavour and most scientific processes involve creativity" (p. 822). Their research surveyed educators in both the United States and South Korea on their feelings and understanding of creativity and creative students. The study comes on the heels of reports from educational agencies in both countries delineating the need for creative students and an emphasis on fostering creativity as a major facet of a teacher's work. The researchers found differences in the ways how teachers understood creativity, for instance, in relation to ethics, "when creativity was used for an unethical purpose … 10% of the participating U.S. teachers and 39% of Korean participating teachers denied that the student was creative" (p. 830). Most participants in the study also believed that creativity could be fostered; however, the majority also did not believe that students had this talent.

According to the participants of this study, however, teaching for creativity was limited due to standardized achievement tests which "require understanding and applying only basic concepts, not creativity" (p. 835). In this way, given the prevalence of standardized testing, science education has become a process of repeating information for the purposes of passing a test rather than the application of concepts as they affect daily life.

The employment of knowledges to daily life is difficult given the ways that science is taught. Deanna Kuhn (2010) in her work proposes an "argumentation curriculum" that exposes students to the different aspects of making an argument. Kuhn, quoting Bricker and Bell (2009), points out that "the goal of science must not only be the mastery of scientific concepts but also learning how to engage in scientific discourse" (p. 810), as such, to Kuhn (2010), "the goal is to communicate and most of all to persuade. Scientific thinking becomes a social activity" (p. 811). However, there is a dissonance here because while scientific thinking is conceptualized as a "social activity", the process is presented in individualized terms and the object is to ensure one's position as the only way of thinking about a problem. Thus, arguing is understood as conflictual rather than collective learning experience where the object is "to secure commitments from the opponent that can be used to support one's argument. The second is to undermine the opponent's position by identifying and challenging weaknesses in the opponent's argument" (p. 813). As such, the learning experience is not relational experience where both individuals push the boundaries of their understanding to arrive at a correct response, instead it is understood as an individualistic process where the object is to devalue the other's point of view and ultimately win. The author goes on to discuss the role of evidence in this endeavour as a necessary facet of the scientific process whereby it can strengthen one's argument as well as weaken the counter argument. However, the author does not speak about the need to engage with all information surrounding a topic rather than only focusing on that which furthers one's argument. This process would then make it difficult for a student to change opinions as an argument goes on since the objective is to win the argument and the shifting of positions can be constructed as undermining one's initial argument. In all, while learning how to effectively argue is a valuable tool, it can be counterproductive as each conversation is then understood as duel where one must discredit the other until victory is proclaimed in such a combative context.

In the teaching of science, many authors focus on the pedagogical employment of the scientific method. This topic is taken up in relation to engaging with inquiry and "scientific questions", learning how to observe and finding ways to employ technology to further scientific thought. Mike Padilla (2010) writes about a perceived need to increase the inquiry skills of students as well as their ability to link those skills to critical thought. He defines inquiry as being "about logic, it's about reasoning from data and it's about applying scientific techniques and skills to real-world problems" (Padilla, 2010, p. 8). With this in mind, Padilla states that "inquiry teaching is an approach that engages student curiosity and wonder, that inspires students to observe and reason and that helps them to sharpen their critical-thinking and communication abilities" (p. 9). Reason and inquiry in this sense requires a positivist and empirical approach that is data driven. According to the

author, inquiry is a process to "engage with a scientific question", "participate in design of procedures", "give priority to evidence", "formulate explanations", "connect explanations to scientific knowledge" and "communicate and justify explanations" (p. 8). Given that "logic" and "reason" is constructed as stemming solely from a specific epistemological method of knowledge production, it becomes important to contest what is understood as logical and how "logic" can be found outside of the Western scientific method.

While we all engage in observing the world around us, the classic scientific model postulates a correct way to engage with observations. McBride and Brewer (2010) see "careful observations" as a "foundation of the scientific process" (p. 40). However, observing is not nearly enough for them in order to engage in the scientific process. Observations must follow a systematized, precise and structured method. As such, while they argue that observation "is fundamental to gathering the evidence that supports scientific understanding" (p. 41), it comes with a caveat as "just looking is not enough; most students require structure and guidance in how to focus and observe with a purpose" (p. 41). McBride and Brewer (2010) then suggest activities that they believe will lead to scientific observations. According to the authors, these activities will begin to show how some scientists begin to collect data as "making an observation means to study or look at something closely. The ability to make careful observations is an important skill for scientists, especially ecologists…. By looking closely at the natural world and studying even the smallest details, an ecologist can begin to ask interesting questions and make good predictions" (p. 42). The activity ends through a process of categorization. Questions are asked about their samples, the process under which they found them, how categories can be created to define and understand their surroundings and what they found surprising about the samples they gathered. In a similar vein to McBride and Brewer, Finson (2010) also focuses on observations and the inferences that can be made about the world through the use of the scientific method. To him, too often, the wrong definition is used for inference in science classrooms including referring to it as "a conclusion or explanation one makes about an object or event and it is based on observations" (p. 45). Rather, he argues, inference should be understood as "one's best explanation for *why* something occurred" (p. 45, emphasis in original). To this end, Finson (2010) lists five tips to help develop better inferences. These include: "an inference is only as good as the observations on which it is based", "an inference is only one of multiple possible explanations for a set of observations", "inferences are not always correct", "inferences are influenced by prior knowledge and experience", [and], "as teachers we need to help our students examine the assumptions they use when making inferences" (p. 46–47). These tips are meant for employing logic; however, logic is not explained and as such taken for granted within a scientific framework that only includes particular knowledges. Given the taken for granted standing of a Western understanding of logic, this endeavour, while attempting to focus and open up science for students can also be quite constricting for the teacher, as is understood as the holder of knowledge, which determines what is deemed logical and what is not, as well as the logical method to go about it.

The current literature also cites technology as an important tool in teaching science. Jimoyiannis (2010) states that while educators find technology to be useful, it is severely under-used. This is the case even though the availability of technology in schools has increased. To this end, Jimoyiannis (2010) and Zhang et al. (2010) both provide possibilities for curriculums centred on the presence and use of technologies. Zhang et al. (2010) particularly focus on mobile technologies that can be used to learn "everywhere and all the time" (p. 1504). Perkins, Loeblein and Dessau (2010) also advocate the use of technology, albeit in a different way. They suggest the use of simulations that "create animated, game-like environments in which students learn through scientist-like exploration" (p. 47). These simulations, they argue, can be used in the absence of equipment in the classroom.

TOWARDS A COUNTER-PEDAGOGY OF SCIENCE EDUCATION

Missing from the foregoing analysis is an understanding of the Indigenous pedagogic ways of science teaching grounded in local knowledge systems. In this section, we first focus on the conceptualization of science and Indigenous knowledge, highlighting studies that have raised pertinent issues for rethinking schooling and education. We contend that for the most part when the topic of 'Indigenous Science' is raised, the focus of the discussion has been how we validate Indigenous knowledges in the academy as 'science'. We want to move away from that to a discussion of the merits of Indigenous Science itself. In so doing, we are disrupting scientism as a framework of knowledge production. We are speaking of science as a tool to answering existential questions and making sense of the connections of people to their cultures, nature/Earth and society. We note that the historical genesis of Western 'science' has tied science to religion itself. As already noted, science has been so culturally contextualized and value-laden, while at the same time making spurious conceptual claims to universality. So one may ask what conceptual claims are we ourselves then making?

In his conceptualization of Indigenous science, Frank Elliot (2009) notes there is a clear dissonance between Western conceptions of science and Indigenous beliefs. Elliot begins his argument by dispelling the myth of objectivity as well as the idea of "scientism" which he defines as "the belief that Western science gives the only real description and explanation of reality. This results in the exclusion of ontological and epistemological understanding of the natural world through other forms of knowledge, specifically Aboriginal ways of knowing" (p. 285). Elliot (2009) links scientism to colonialism by quoting Peat (2002) as stating that "a dominant society denies the authenticity of other people's systems of knowledge" (p. 285). A key point to Elliot's argument is the inability to distance the knower from the known and the need to understand knowing as a process. Elliot (2009) uses his arguments about the dissonance between Western science and Indigenous peoples to explain the marginalization that happens to Indigenous students within science classrooms as well as to suggest a new way to understand science through metaphor. Cajete (2000) is quoted as stipulating that "[N]ative science is used as a metaphor for [N]ative knowledge and participation in the natural world in both theory and practice" (p. 289). In all, according to Elliot the inability to explain

meaning in the science classrooms leads to disenchantment from science in the part of Indigenous students. As such, Elliot utilizes Aikenhead's (2006) concept of "humanistic science" to develop a new paradigm that links Western science with a conceptual shift mediated by metaphoric meaning. This model "introduces new perspectives of human cognition and meaning-making, as well as new approaches to scientific objectivity and observations of self and others. From a Western scientific perspective, this includes cognitive and affective understanding of events in the natural world" (p. 296).

Similar to Elliot's conceptualization of the false prescribed divergence between Western understandings of science and Indigenous knowledge, Bradshaw (2010) writes about trans-species communication. He begins by relating the long history of Indigenous peoples speaking to animals and then by refuting what used to be mocking discourses of these practices through the use of Western science. Bradshaw (2010) explains the framework employed in Indigenous communities regarding "wildlife communities" where they were generally treated as sovereign nations with authority equal to, if not greater than, that of humanity" (p. 408). While these conceptualizations were mocked, some elements of Western science have begun to adopt similar understandings whereby "slowly, modern humanity is turning from anthropocentrism toward ecocentrism: away from ways of being that separate humans from other animals and a return to those that bring multiple species into community" (p. 408). Beginning by citing studies finding little genetic difference between animals and humans, Bradshaw (2010) states that science has found what Indigenous people have known, that "other animals posses (sic) capacities formerly assumed to be uniquely human and neuropsychological discoveries have led to a species-inclusive model of the mind depicting humans and other animals … with virtually the same neurobiological structures and mechanisms underlying what seemed to make us special, including cognition, emotions, ethics, decision-making, a sense of self, the capacity to suffer psychologically and vocal learning (p. 409).

In this way, the capacity for humans to interact and communicate with animals is highlighted by citing individuals who have lived with lions, bears, elephants and birds. These experiences are understood as employing forms of communication whereby meaning can be derived. Speech then is critiqued as an ineffective method of communication and as such an unacceptable excuse for believing animals are unable to communicate, as Bradshaw (2010) states "the 'verbal channel' is a relatively poor medium of expressing the quality, intensity and nuancing and emotion of affect in different social situations" (p. 414). This then can challenge beliefs that the ability to engage in human speech provides the holders of such language as superior species. At the same time, it provides a way to imagine other forms of communication as more developed and complex. Finally, Bradshaw (2010), after explaining the close link between humans and animals, as well as their ability to communicate, critiques the use and abuse of animals as unethical and cruel and as part and parcel of the supremacist belief of humans over nature.

Other writers have also taken up Indigenous knowledges to critique the limitations of Western science. Some researchers take up such knowledge in the

context of ecology and conservation. Peloquin and Berkes (2009) describe the ways in which Indigenous knowledges encompass complex understandings of the ecology in which people live. They argue that while "Western science based societies have tended to simplify ecosystems in order to manage them … the environmental monitoring practices of some Indigenous and rural societies are significant in identifying ways to perceive the continuum of nature holistically" (p. 533). These practices by Indigenous societies they argue, allow for the replenishment of valuable resources rather than prioritizing some resources while squandering all others such as in science-based management practices. However, at the same time the authors provide an argument of Indigenous science as having a greater understanding of a phenomenon than Western science, they discredit the intervention by employing terminology that ultimately devalues such knowledge. Peloquin and Berkes (2009) place Indigenous ways of knowing in a category termed "fuzzy science". They explain fuzzy science as "a form of multi-valued logic that seeks explanation through approximate rather than numerically precise reasoning" (p. 535). While the authors explain that "fuzzy science" is used in different disciplines including "computer programming, engineering and environmental monitoring and assessment" (p. 535), it also appears as a back-handed comment as it creates a binary between real or clear science and "fuzzy science". Of course, given the ways in which Indigenous knowledges are delegitimated, they are relegated to the latter.

What ultimately appears to be the argument for Peloquin and Berkes (2009) is that science has a quantitative basis while Indigenous ways of knowledge are based on a complex understanding of qualitative factors. As such, the authors state that "there is a distinction to be made between knowledge as content versus ways of knowing. The former is static and assumes that knowledge can be treated as something that can be transferred from one container to another. The latter is dynamic and focuses on the way knowledge is acquired through practical experience" (p. 585). However, there is still an understanding that through the employment of a separate prism labeled as "fuzzy science", Indigenous knowledges do not belong in the "science" category or fit within a limited category that is less noteworthy. In order to explain the complexity of the method employed by Indigenous people, the authors provide information from a study in the James Bay where Indigenous peoples have studied a myriad of factors that affect their geese hunts. Peloquin and Berkes (2009) provide a number of factors that are taken into account by the hunters to determine when and how to hunt. These factors include the need for places to "rest" to diffuse "hunting pressure in space in time, with the goal of not disturbing migratory geese past a threshold beyond which they would avoid the territory altogether" (p. 537). As the geese hunts have produced less and less geese, Peloquin and Berkes (2009) highlight the explanations provided by hunters. These explanations include the encroachment into their territories by government bodies, industrial interests, changing climate, transgressions of hunting rules, availability of berries which serve as food for the geese, etc. These factors explain the complexity of the Indigenous ways of knowing as well as a clear understanding of the many factors that can affect a single activity, the hunting of geese. The authors attempt to display the compilation of factors through a model

but given the complexity it appears as if the limitations of maps cannot nearly cover the overall complexity of the understanding of such an environment.

As noted repeatedly, Indigenous ways of knowing are highlighted by their ability to remain dynamic to the changing conditions of their environment. An example is a study by Orlove, Roncoli and Kabugo (2010) which focuses on knowledge of climate weather by a group of people in southwestern Uganda. The authors begin by operationalizing the term "Indigenous knowledges" to mean "the place-based knowledge that is rooted in local cultures and generally associated with long-settled communities which have strong ties to their natural environments" (p. 244). This knowledge, they argue, "tends to be the result of cumulative experience and observation, tested in the context of everyday life and devolved by oral communication and repetitive engagement rather than through formal instruction" (p. 244). In contrast to what they term "modern science", the authors state that Indigenous knowledges are "a flexible entity, which by virtue of [their] diverse and empirical nature, can easily integrate skills and insights from other knowledge systems as well as from experimental practice" (p. 244). Orlove, Roncoli and Kabugo (2010) then go on to explain the need for knowledge of climate systems given the importance of "agriculture… [and a] domestic water supply" (p. 247). Climate knowledge is of the utmost importance given its scarcity, a limited labor supply due to the AIDS epidemic, high cost of seed and the vulnerability to predatory lending. As such, farmers in this region depend on a system of knowledge regarding historical climate patterns that predates generations. According to the authors, "the collective memory of the farmers in the district stretches back at least to the early decades of the last century, well before the beginning of [weather-related] data collection at the nearby meteorological stations" (p. 252). People also employ a number of signs to determine the coming of rain including an increase in nighttime temperature, shifts in prevailing winds, the flowering of trees and the arrival of migratory birds. The flowering of coffee trees represents a dynamic nature of the knowledge system since the trees are relatively new and there is not a long history of coffee production in the region. Finally, individuals employ a "social nature" to knowledge as they share information about weather with travellers and in their travels. These elements, to the authors, represent a system that relies "on a variety of spatial, temporal and social scales" (p. 261) while also maintaining a strong practical emphasis and enabling the possibility of including new elements. It is interesting to note that even after explaining the complexity of the process under which knowledge in relation to this phenomenon is created as well as the ways under which it has been tested, the term science is not employed to define it. This may speak to our collective deficiencies in conceptualizing science as a concrete practice only happening within specific spaces by particular bodies and labeling all other methods of knowledge production as being either "fuzzy" or well outside the boundaries of "science".

There is a large dissonance between Western science and traditional ways of knowing. Deborah McGregor (2009) takes up this issue by first distinguishing between different understandings of "traditional knowledge" and then providing

three examples of ways in which such knowledges have been taken up in projects attempting to incorporate it. According to McGregor (2009), terms like "traditional knowledge" tend to connote a false homogeneity of knowledge across the diverse nations and cultures of Aboriginal peoples. She adds "as well 'traditional' implies that the knowledge is static and confined to information gained in the past" (p. 73). With this in mind, McGregor (2009) outlines differences between "traditional knowledges" and western knowledges, she writes:

> "traditional knowledge is both more and different from Western definitions…. Aboriginal understandings tend to focus on *relationships* between knowledge, people and all of creation. Traditional knowledge is viewed as the *process* of participating fully and responsibility in such relationships, rather than specifically the knowledge gained from such experiences. For Aboriginal peoples, traditional knowledge is not just about understanding relationships; it *is* the relationship with creation" (p. 75, emphasis in original).

While there have been many attempts to understand traditional knowledges, these have often involved Western scientific research frameworks. McGregor (2009) argues that as a result, traditional knowledge is "frequently reduced to a catalogue of information" (p. 76). There are also a number of barriers hindering the use of traditional knowledges including "Aboriginal people are not accorded *meaningful participation* in studies and other work that should and in some cases does attempt to use traditional knowledge"; "Aboriginal people and their knowledge are viewed as *objects* suitable for *study* rather than as *people* for *working with*"; "Aboriginal people have little *control* over how the knowledge they share will be used. Such knowledge can be (and has been) used against its original holders, or otherwise abused, at a later date" (p. 77). To further her point regarding the different ways in which traditional knowledge and Aboriginal peoples can be engaged in initiatives in Ontario, McGregor outlines three cases. These cases are a state-led initiative, a co-operative initiative between the province and the Anishinabek Nation and a case where a First Nation is in the "driver's seat." These cases, given the ways they are conceptualized engage with traditional knowledges and the holders of such knowledges in vastly different ways.

REVISIONING SCIENCE EDUCATION IN THE AFRICAN CONTEXTS

A number of scholarly works in and on Africa have problematized science and in particular school science and the place of Indigenous knowledge in school curricula. In his pioneering work, Jegede (1994) explores the ways in which non-Western socio-cultural perspectives affect the teaching of Western science in Africa. He considers the fact that in Africa, science teaching is limited to giving information "rather than encouraging critical and creative thinking and the personal construction of knowledge" (p.122). In particular, Jegede (1994) sees Science-Technology-Society [STS] education can help bridge the gap between traditional African values and Western scientific values. It is asserted that STS can help Indigenous science studies (e.g., tunning, craft, painting, printing and communication) integrate with

modern technology. The author claims that in STS education, one needs to do a couple of things: first, use familiar materials and processes; second, teach and learn science through Indigenous technology and third, employ accommodation and assimilation (co-existence between cultural values and Western science). Jegede (1994) notes that "Africa had and still has its own science and technology [and that] these were based on very different conceptual and cognitive models, which were not apparent to, or regarded by, the colonialists who first introduced Western education to Africa" (p.121). Historically, it was assumed that African peoples had no science (see Maddock, 1981). Jegede (2004) shows in his work the differences between African and Western science. The former is "monistic-vitalistic" (see also Odhiambo, 1972), metaphysical and based on people. Western science is mechanistic, exact and hypothesis-driven which seeks empirical law, principles, generalization and theories. Jegede (1994) argues that the problem occurs when "the African must learn Western science against the backdrop of myriad sociocultural factors brought from the traditional environment. (p.122). He refers to Knamiller's work (1989) linking school science with Indigenous science and technology in Malawi and notes this quote:

"One of the reasons why school science has remained alien to most African children is because we often fail to take into account the science and technology local people are doing, what knowledge and skills they have and what problems they feel are important to consider" (see Knamiller, 1989, p. 2.).

Jegede (1994) concludes with the suggestion of a "conceptual ecocultural paradigm" which is a "state in which the growth and development of an individual's perception of knowledge is drawn from the sociocultural environment in which the learner lives and operates" (P. 130).

Keane's (2008) relatively recent work explores the ways in which science educators can contribute to both meaningful science education and community well-being through understanding key aspects of an African worldview in Zulu community. Relying on the South African case study of 2005 when the National Research Foundation formed focus groups on Indigenous Knowledge system and repeated calls for development and inclusion of Indigenous Knowledges [IK] come from academics, the focus was on how school science can contribute to solving problem in relation to environmental issues. Keane (2008) notes that "[a]ttempts to include IK in textbooks usually consist of traditional "bit that fit" into the current syllabus (i.e., only fragments of IK). This is a gross oversimplification of IK preservation and it demonstrates our Western science hubris" (p. 589). She further observes that "even when IK examples are currently included in science curricula, the examples occur within a Western science paradigm" (p. 589). Through her study at science education for two schools in rural communities, she highlights some themes critical to acknowledging a collective Chibini worldview, such as history, medicine, nature, water, time and Ubuntu. She states that "[e]ducators and curriculum designers in South Africa need to understand the role of worldview related to these themes" (p.610).

Le Grange (2007) has also argued for rethinking the science education in South Africa. The study examines the ways in which Western science and Indigenous

knowledge might be integrated in South African education. Le Grange (2007) notes that while much has been written over the years about complications African learners experience when learning science (see for example such pioneering works as Ogawa, 1986; Ogunniyi 1987, 1988; Jegede, 1989; Jegede & Okebukola 1989; Jegede & Fraser 1990; Okebukola & Jegede 1990; Jegede 1996), the topic of African Indigenous knowledge has not been given the attention it deserves. Le Grange's (2007) work attests to the importance of including Indigenous knowledge into the curriculum as theoretically enshrined in National Curriculum Statements. There is recognition of how the achievement of such ideals depends on teachers' understanding of the interaction between Western Science and Indigenous knowledge and their ability to manage classroom discourses related to this matter. It is contended that science is "performance" rather than "representation". Students are often required to learn to view science as "representation" to the neglect of science as "performance". Science as representation refers to abstractions such as theories and rules of scientific method and descriptions of the world in the textbook. On the other hand, science as performance refers to the doing of science. In such case, science is a human and social activity that is messy, heterogeneous and situated. According to Le Grange (2007), what students do not learn with the science as "representation perspective" is the "situated messiness of science" (p.586). The author claims the representationalist perspective on knowledge produces an incommensurability perspective that is "Western science and Indigenous knowledges are incompatible or that Indigenous ways of knowing may be recognized as a particular way of understanding the world, but that they are not science" (p. 586). Understanding knowledge production as performance may enable Western science and Indigenous knowledge to work together in the "third space" (Turnbull, 1997, p. 560). Le Grange (2007) also states that focusing on performative side of science leads to understand science is a situated activity which connects people, sites and skill. After all, "science is locally produced through processes of negotiation based on the social organization of trust and not empirical verification/falsification" (Le Grange, 2007, p. 589).

Bringing Indigenous knowledge as science to school curriculum goes beyond the disciplines of social studies and humanities. Studies by Dalvit, Murray and Terzoli (2008) point to the implication of Indigenous knowledge and language for computer science education. These authors point out that on one hand, computer science is seen as empowering students in Africa in terms of economic and global accessibility. However, since most computer-related knowledge inevitably reflects Western assumptions and ways of thinking, it makes it difficult subjects of study for students who have difficulty in accessing the infrastructure and working with unfamiliar paradigms. The authors, therefore, emphasize the need to integrate Indigenous knowledge in teaching of computers to respond to local problems. On the teaching and learning of Indigenous language and knowledge in ICT (information and computer technology) education, [which the authors call "ethnocomputing"] the emphasis is on the importance of integrating cultural elements into software design and the teaching of computer science. In their work, Dalvit, Murray and Terzoli (2008) refer to a study by Duveskog, Sutinen, Tedre and Vesisenaho (2003) in Tanzania on the use of fractals in traditional arts and

crafts as the method to aid the teaching of computer science. They point out that Ubuntu, African philosophical concept, has named one of the most popular Linux distributions, which values of sharing and emphasizes the interdependency between humans. Ubuntu captures the spirit of open source community more precisely than comparable Western terms. In effect to further African youth education in computer science, the authors call for a new software programme for marginalized students. In their project at Rhodes University, they developed and tested materials (more than 150 computer terms) in isiXhosa which also integrates multimedia. This programme was developed with students' input. The authors conclude that culturally appropriate metaphors and examples that support existing computer skills course help students build their confidence and uncover the potential of their own local languages and cultural knowledges to help them academically.

Ezeifa (2003) draws on his experience teaching mathematics to Indigenous students in Canada, America and African countries. He unequivocally states that the integration of Indigenous knowledges such as folklore, myths, legends and taboos in science and mathematics education, will help address current issues of low enrolment and academic performance of students from Indigenous cultures. The author argues that while Indigenous communities of African, Asian, Mayan, Hispanic and Aboriginals contribute to the development of science and mathematics (for example, the modern system of numerals, negative number, concepts of congruence, Algebraic concepts, etc.) their contributions are largely ignored in textbooks. Ezeifa (2003) argues the lack of teaching Indigenous students' real life and "place" they live (where they are connected to, physically, psychologically and spiritually) in the science and mathematics curriculums and current methods of teachers is a huge problem. The author argues the distance from the connection between the subject areas and "place" [home environment] is one of the strong reasons why students feel alienated from science and mathematics. Regarding to the teaching methods, students from Indigenous cultural background usually adopt the holistic approach to information processing and also field-dependent learners.

Bringing local cultural knowledge into school science education in Africa will demand that we rethink some of our deeply held reservations about cultural forms of knowing. We argued in the introductory chapter, for example, about the place of spirituality in schooling and education. As we move forward in educating young learners for tomorrow, we have to grapple with key questions about science education that implicate spiritual knowings: How do we teach local cultural knowledge as Indigenous science that emphasizes a physical and metaphysical interdependence and connections? How do we approach science and technology studies that connect with local learners and their surrounding social and physical environments? How do we work with Indigenous spiritual ontology that asserts the universe is basically a spiritual universe? How do we broach the teaching of spiritual identity as a way of knowing in schools? These are not questions with easy answers. Elsewhere, one of us has proposed the creation of what he has termed a 'trialectic space' in schools (see Dei, 2011). This space will involve a dialogue among multiple parties a sort of 'dialogic encounters' with an epistemic

community. But more importantly, it is constituted as a space for learners to openly utilize the body, mind and spirit/soul interface in critical dialogues about their education. It is also a space that nurtures conversations that acknowledges the importance and implications of working with a knowledge base about society, culture and nature nexus. Such spaces can only be created when we open our minds broadly to revision schooling and see schooling as place/site and opportunity to challenge dominant paradigms and academic reasoning.

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REFERENCES

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence based practice*. London; ON: Althouse Press.

Bradshaw, G. (2010). You see me, but do you hear me? The science and sensibility of trans-species dialogue. *Feminism & Psychology, 20*(3), 407–419.

Buss, R. R. (2010). Efficacy for teaching elementary science and mathematics compared to other content. *School Science and Mathematics, 110*(6), 290–297.

Cajete, G. (2000). *Native science*. Santa Fe, NM: Clearlight.

Castellano, M. B. (2000). Updating aboriginal traditions of knowledge. In G. J. S. Dei, D. Goldin Rosenberg, & B. Hall (Eds.), *Indigenous knowledges in global contexts* (pp. 21–36). Toronto: University of Toronto Press.

Dalvit, L., Murray, S., & Terzoli, A. (2008). The role of indigenous konwledge in computer education in Africa. In M. Kendall & B. Samways (Eds.), *Learning to live in the knowledge society* (pp. 287–294). Boston: Springer.

Dei, G. J. S. (2011, March 25). *The lessons of indigenous philosophies for critical education*. Keynote address at the 4th Annual Conference on 'Decolonizing the Spirit'. Toronto: Ontario Institute for Studies in Education of the University of Toronto.

Duveskog, M., Sutinen, E., Tedre, M., & Vesisenaho, M. (2003). *In search of contextual teaching of programming in a Tanzanian secondary school*. IEEE conference Frontiers in Education (FIE), November 5–8. Boulder.

Elliott, F. (2009). Science, metaphoric meaning and indigenous knowledge. *Alberta Journal of Educational Research, 55*(3), 284–297.

Ezeife, A. N. (2003). Using the environment in mathematics and science teaching: An African and aboriginal perspective. *International Review of Education, 49*(2–4), 319–342.

Finson, K. D. (2010). Tips for teaching students about the importance of quality inferences. *Science and Children,* October, 44–47.

Hong, M., & Kang, N.-H. (2010). South korean and the us secondary school science teachers' conceptions of creativity and teaching for creativity. *International Journal of Science and Mathematics Education, 8*(5), 821–843.

Jegede, O. (1989). Towards a philosophical basis for science education of the 1990s: An African view point. In D. Herget (Ed.), The history and philosophy of science in science teaching (pp. 185–198). Tallahassee: Florida State University.

Jegede, O. (1994). African cultural perspectives and the teaching of science. In J. Solomon & G. Aikennhead (Eds.), STS education: International perspectives on reform (pp. 120–130). New York: Teachers College Press.

Jegede, O. (1996). In support of culturally and individually responsive science education graduate programmes for international students: Comment on Lunetta and van den Berg. *Science Education, 80*, 101–104.

Jegede, O., & Fraser, B. (1990). The effects of instruction on science students: Sociocultural attitudes and achievement. *Singapore Journal of Education, 1*(1), 12–18.

Jegede, O., & Okebukola, P. (1989). Some sociocultural factors militating against drift towards science and technology in secondary schools. *Research in Science and Technological Education, 7*(2), 141–151.

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science framework for science teachers professional development. *Computers & Education, 55*(3), 1259–1269.

Keane, M. (2008). Science education and worldview. *Cultural Study of Science Education, 3*, 587–621.

Knamiller, G. (1989). Linking school science and technology with school science in Malawi. *Science Education Newsletter, 84*, 1–3.

Kuhn, D. (2010). Teaching and learning science as an argument. *Science Education, 94*(5), 810–824.

Le Grange, L. (2007). Integrating western and indigenous knowledge systems: The basis for effective science education in South Africa? *International Review of Education, 53*, 577–591.

Maddock, M. N. (1981). Science education: An anthropological view-point. *Studies in Science Education, 8*, 1–26.

McBride, B. B., & Brewer, C. A. (2010). Nature's palette: Budding ecologists practice their skills of observation in this color-wise investigation. *Science and Children,* October, 40–43.

McGregor, D. (2009). Linking traditional knowledge and environmental practice in Ontario. *Journal of Canadian Studies, 43*(3), 69–100.

Odhiambo, T. R. (1972). Understanding of science: The impact of the African view of nature. In P. G. S. Gilbert & M. N. Lovegrove (Eds.), *Science education in Africa* (pp. 39–46). London: Leinemann.

Ogawa, M. (1986.) Towards a new rationale of science education in a nonwestern society. *European Journal of Science Education, 82*, 113–119.

Ogunniyi, M. (1987). Conceptions of traditional cosmological ideas among literate and non-literate Nigerians. *Journal of Research in Science Teaching, 24*(2), 107–117.

Ogunniyi, M. (1988). Adapting western science to traditional African culture. *International Journal of Science Education, 10*(1), 1–9.

Okebukola, P., & Jegede, O. (1990). Ecocultural influences upon students' conceptual attainment in science. *Journal of Research in Science Teaching, 27*(7), 661–669.

Orlove, B., Roncoli, C., & Kabugo, M. (2010). Indigenous climate knowledge in southern Uganda: The multiple components of a dynamic regional system. *Climatic Change, 100*(2), 243–265.

Padilla, M. (2010). Inquiry, process skills and thinking in science. *Science and Children,* October, 8–9.

Peloquin, C., & Berkes, F. (2009). Local knowledge, subsistence harvest and social-ecological complexity in james bay. *Human Ecology, 37*(5), 533–545.

Perkins, K. K., Loeblein, P. J., & Dessau, K. L. (2010). Sims for science powerful tools to support inquiry-based teaching. *The Science Teacher,* October, 46–51.

Turnbull, D. (1997). Reframing science and other local knowledge traditions. *Futures, 29*(6), 551–562.

Zhang, B., Looi, C.-K., Seow, P., Chia, G., Wong, L. H., Chen, W.,…Norris, C. (2010). Deconstructing and reconstructing: Transforming primary science learning via a mobilized curriculum. *Computers & Education,* 55(4), 1504–1523.