Human Rights in Language and STEM Education

Science, Technology, Engineering and Mathematics

Zehlia Babaci-Wilhite (Ed.)

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Science, Technology, Engineering and Mathematics

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This book is dedicated to everyone deprived of learning STEM subjects in ways that contribute positively to their personal and professional development as well as to their capacity to make a contribution to the development of their local, national and global communities.

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ZEHLIA BABACI-WILHITE

INTRODUCTION

The inspiration for this book emerged from my affiliation at the *Graduate School of Education and the Lawrence Hall of Science at the University of California, Berkeley, USA* where I was exposed to the importance of language in the teaching and learning of Science, Technology, Engineering and Mathematics (STEM) subjects. Professor David Pearson and Jacquie Barber, founders of the Seeds of Science and Roots of Reading curricula introduced me to insightful ways of learning and teaching science using a theory of inquiry that emphasizes the use of local context and thus fits well with learning science in the language that teachers and children master best. Professor Pearson and several other scholars from the Lawrence Hall of Science have made important contributions to this volume.

My interest in language and learning in Science and Mathematics began with my research in Zanzibar and Nigeria, where I studied language policies in African curriculum. A central finding from these studies was that the use of a local language was crucial to the learning of science. This was the subject of my previous book entitled "Local Languages as a Human Right in Education" (2015, Sense Publishers). I am currently continuing this line of research in Nigeria where I am affiliated to the *Imo State University (IMSU), Owerri*, as well as the *International Society of Comparative Education Science & Technology*, *Yenagoa, Bayelsa State, Nigeria*.

While teaching students from the Masters and Credential in Science and Mathematics Education (MACSME) program at the University of California, Berkeley, my understanding of the importance of using Cultural as and Artistic concepts to facilitate teaching and learning Mathematics grew, and my work benefited from using concepts from Ethnomathematics in the teaching of Science. Inspired by the extensive work of Professor Ubiratan D'Ambrosio who contributed an important chapter to this volume, my interest in Science and Mathematics in Africa expanded to include the use of digital Technologies for teaching Science and Mathematics.

I was fortunate to have the opportunity to audit Professor Jabari Mahiri's class on Digital Devices in Urban Education, which expanded my perspectives on the use of digital technologies in the classroom. Professor Mahiri has co-authored an interesting chapter in this volume with one of his PhD candidates, Jeremiah Sims.

Based on our collaborative work with another contributor to this volume, Professor Inga Bostad, the Director of the *Norwegian Center for Human Rights at the University of Oslo* where I am currently affiliated as a Visiting Scholar, Mahiri and I have developed a project focusing on Diversity, Technology and Human Rights in collaboration with the University of Tromsø. Dr. Lanette Jimerson who co-authored a chapter in this volume joined the project as well. This cross fertilization of perspectives on Science, Mathematics and Technology between the USA and Norway has linked STEM education to Language and Human Rights as well as to my work with the teaching of STEM subjects in Africa. The collection of chapters in this volume addresses various facets of the effort to improve the learning of Science and Mathematics.

This volume draws on a unique and diverse set of authors from the USA, Norway and Africa. There are excellent contributions by several scholars from Nigeria, Professors Macleans A. Geo-JaJa and Steve Azaiki as well as PhD candidate Basil Okonkwo, as well as from Malawi, Professor Mchombo and from Tanzania, Professor Ladislaus M. Semali. The contributions of the African authors demonstrates the linkages between local languages, human rights and STEM subjects in Education arguing that Africa has so far largely been excluded from the transformation that is going on in STEM pedagogy in the USA, where considerable emphasis has been placed on language and the development of English Language Learner (ELL).

My work in Africa started with another contributor, Professor Birgit Brock-Utne, the Norwegian leader of the Language of Instruction (LoI) in Tanzania and South Africa (LOITASA) project based at the University of Oslo, the University of Dar es Salaam (Tanzania) and the University of Cape Town (South Africa). The LOITASA project transformed to a new project called Transformation in Language and Education (TRANSLED) in collaboration with the University of Oslo, the State University of Zanzibar and the University of Dar es Salaam. As I have argued in previous publications, in its recent curriculum reform in Zanzibar, English was introduced as the primary LoI for Science and Mathematics subjects in higher primary grades without giving it the English Language Learner importance that it deserves. This change has thrown up new pedagogical challenges to the teaching of Science and Mathematics. My research about this curriculum change has revealed weaknesses in teacher preparation, teaching materials and pedagogy, and student comprehension in the transformation from learning in their own language to learning in English (see Babaci-Wilhite, 2013, 2014 and 2015).

Several of the contributions to this volume focus on the curriculum changes in language and STEM subjects within a global versus local curriculum. Other chapters explore the challenges of teaching and learning STEM subjects in local contexts in a range of countries around the world such as Suriname, addressed in the chapter of Emmanuelle Le Pichon and Ellen-Rose Kambel; the Philippines by Brad D. Washington; in Pakistan by Abbas Rashid, Irfan Muzaffar, Fatima Dar and Salaeya Butt; and by Lanette Jimerson and Page Hersey in the U.S.A.

I ended the previous volume I edited with a poem reminding us of Paulo Freire's legacy in Education Rights and his contribution to critical pedagogy. I decided to start this volume with Paulo Freire's legacy in Education Rights linked to the STEM introduced by a Poet-Artist, Gregory Johnson who articulated in his poem the importance of Art to creativity in the STEM subjects for a critical and innovative Education. Johnson's work in the Ethnomathematics and the Geometry of Art captured through his second poem concludes this volume.

ORGANIZATION OF THE BOOK

This volume comprises 15 chapters in addition to this introduction, the foreword and afterword through the 2 poems. The chapters are divided into four parts:

I – Human Rights in Language and Science Literacy
II – Equity and Critical Pedagogy in Technology and Human Rights Education
III – Language of Instruction in Science and Technology
IV – Human Rights in Mathematics and STEM Education

The contributions to *Part I* – entitled *Human Rights in Language and Science Literacy* address and analyze the knowledge as well as the methodology used to inquire science learning, the art of reading science and the practice of scientific argumentation. Reading should take place to support children to learn all subjects in order to acquire a language that will facilitate their learning process. The authors claim that its importance is a human right in education.

In the first chapter entitled "The Use of Local Languages for Effective Science Literacy as a Human Right", *Zehlia Babaci-Wilhite* addresses curriculum change in education and science literacy by exploring how to enable Science literacy through an inquiry-based approach in Africa. Further, it argues that learning in schooling should be based in local knowledge and that this ought to be defined as a right in education. The argument is framed with the theory that regards language as powerful tool for learning both in dominant and non-dominant cultures, and that science learning is improved when local knowledge and local languages are used. In other words, the theory of inquiry so important to science is best conducted in a local language. Using a local language in Science teaching will improve teaching and learning and will form a basis for new innovative learning. Implementing a new contextualized model of teaching and learning science will also support and enhance African languages and culture and should take its rightful place as a human right in education.

In their chapter entitled "Reading to Learn Science: A Right That Extends to Every Reader—Expert or Novice", *P. David Pearson* and *Alison Billman* argue that Literacy educators have traditionally assumed that "first you learn to read and then you read to learn." This view has been responsible for a host of practices that have led to a focus on basic skill literacy instruction in primary grades to the exclusion of reading to acquire the knowledge and inquiry skills available in disciplines like Science, literature, or history. In this chapter the authors explain and elaborate a model of integrated Science and literacy instruction that challenges many of these prevailing assumptions about early literacy learning. The key elements in the alternative model are (a) to employ both first hand (hands-on inquiry) and second hand (text-based inquiry) investigations on a topic from the outset of kindergarten, and to employ reading, writing, and language as tools (not goals), whose job is to aid in the acquisition of knowledge and inquiry in science. The authors close with a set of principles that teachers and schools can use to develop programs in which students read to learn while they are learning to read. The goal is to promote the human right to acquire knowledge about how the natural world works from the outset of schooling.

The third chapter entitled “Designing Standards-Driven Curriculum to Support Access to Science for All Students”, by *Megan Goss, Helen Min* and *Carrie Strohl,* provides details on how one program created a CCSS- and NGSS-aligned Science curriculum for middle school using an argument-based, disciplinary literacy approach. This work started with the creation of Seeds of Science/Roots of Reading, as a joint project between the Lawrence Hall of Science and the Graduate School of Education at the University of California, Berkeley. The current curricular development followed a shift by researchers and practitioners to infuse more discipline-focused practices in content area classrooms. The examples included in this chapter focus on the practice of scientific argumentation because it is a central practice of Science, providing students authentic opportunities to engage in talk, reading, and writing around science ideas. Students actively collaborate in the construction of science knowledge as they develop the skills, strategies, and habits involved in scientific argumentation. This chapter supplies explicit curricular examples of argumentation from the units, to illustrate how students, over time and with practice, might build argumentation skills while also gaining Science content knowledge.

The contributions of *Part II* – entitled *Equity and Critical Pedagogy in Technology and Human Rights Education* take on the debate on technology in schools and the critical pedagogical approach to teaching and learning STEM subjects. Critical pedagogy will facilitate critical inquiry for a sustainable education drawing in the Universal Declaration of Human Rights (UDHR). The contributions address the broad implications that educational settings can have on STEM subjects through Technology and its connection to ethics and human rights. The contributions give their focus to African American learning challenges.

In the first chapter entitled “Engineering Equity: A Critical Pedagogical Approach to Language and Curriculum Change for African American Males in STEM” *Jabari Mahiri* and *Jeremiah Sims* demonstrate that pedagogical approaches to STEM education often fail particular student populations, and this is especially true of African American males. This study investigated a critical pedagogical approach to teaching and learning STEM subjects in an after school program that systematically connected the cultural backgrounds, experiences, and interests of middle school African American males to the development of identities with and competencies in STEM. A range of qualitative data was collected on the students’ participation in the program for two to three Saturdays per month during a full academic year. Findings were that this approach significantly increased these students’ competencies in STEM as well as their abilities to identify as emerging STEM practitioners in conjunction with greater understandings of how to use STEM in socially just and responsible ways. This work has implications for broadening access to STEM in school as well as after-school educational settings.

In their chapter entitled "Curriculum and Social Change in Education for a Sustainable Future? Ecophilosophy, Critical Inquiry and Moral Dilemmas", *Inga Bostad* and *Aled Dilwyn Fisher* contend that Education for Sustainable Development (ESD) is increasingly seen as depoliticised, leaving normative premises that promote neoliberalism and leave instrumentalist labour market demands unexamined. Likewise, environmental education's assumptions that education in, for and about 'nature' engender environmental consciousness require critical scrutiny regarding kinds of education in and about nature that are necessary, the role of teachers and, fundamentally, ideas about 'nature' promoted, particularly whether these encourage a romantic 'society'-'nature' dualism that ignores a socio-ecological approach based on the interconnectedness of humans, knowledge and physical systems. The authors explore how 'pluralistic' education can become relativistic or privilege normatively-loaded conceptions of 'pluralism,' while illustrating ESD's frequent instrumentalism. As an alternative, the authors explore socio-ecological pedagogy encouraging: critical reflection over values and ethics, including normative problems in scientific dissemination; a reconnection with the physical through ecology and the natural sciences; and seeing ecological issues as distinct from but, simultaneously, inextricably linked with socioeconomic relations and politics.

In their chapter entitled "Localizing Human Rights Education through Technology: Two Literacy Based Examples", *Lanette Jimerson* and *Page Hersey* argue that from the civil rights movement to 'black lives matter', California has been a geographic space of activism and struggles for social justice. These movements make visible how human rights activism is always local and global. Issues such as police brutality, worker's rights, and immigration impact students' lives and as such human rights education is fundamental to any education that seeks to develop a democratic citizenry. Furthermore, human rights education curricula that connect students to local, regional, and global struggles for justice through the use of technological tools can deepen students' ability to critically read the word and the world. In this chapter drawing on the UDHR, the authors present two critical literacy-based examples of localizing human rights research through technological tools. In the first classroom, ninth grade students investigate the promise and limitations of the pursuit of happiness in relation to UDHR Articles 23 and 25, writing from the philosopher John Locke's, and several canonical texts. Students engage technological tools to gather data, collect interviews, and communicate their lived experience and friends and family members' quest for human rights. In the second classroom, middle school special education students examine police brutality through blogging. Much like the research of Mahiri (2011), blogging provides the ability of youth to communicate and speak against experiences of societal violence both locally and globally. Implications of these two studies highlight the effectiveness of transformative classroom spaces wherein students engage technological tools to make personal and local connections to human rights.

In the contribution of *Part III* – entitled *Language of Instruction in Science and Technology* the authors address changes in Language of Instruction (LoI) in science and technology. A critic of the use of English as a dominant language is discussed within the context of Africa and Asia with the argument that the use of local languages in education is a necessity to facilitate the learning process. The authors conclude that English should be taught as a foreign language and indigenous languages should be used in science and technology. English as Medium of Instruction (MoI) has not been effective in the teaching of science and technology; on the contrary, using several examples, the authors demonstrates that it has had a detrimental effect.

In the first chapter entitled "English as the Language of Science and Technology" *Birgit Brock-Utne* starts with a story from the author's own research experience in Tanzania where she came across a student who hardly understood anything the teacher was saying yet felt that the LoI had to be English since "English is the language of Science and Technology." The author dwells on this unfounded belief in many so-called Anglophone countries in Africa that Mathematics and Science are best taught in English and not in an African language that the language pupils and teachers normally speak and command much better than English. Examples are given from Tanzania, South Africa, Botswana, Lesotho, Zambia and Ghana. The reintroduction of English from the 5th grade in primary school in Mathematics and Science in the Kiswahili speaking island of Zanzibar is discussed at some length. Examples from Africa are contrasted with examples from some Asian countries like Sri Lanka and Malaysia. The attitudes of parents which are built on a misconception are analyzed. The chapter ends on a more optimistic note claiming that misconceptions can be altered.

In the chapter entitled "Language, Scientific Knowledge and the 'Context of Learning' in Africa" *Sam Mchombo* takes on the debate on Nation building in post-independence Africa, which has revolved around the attainment of national unity and identity, as well as the adoption of programs of national development and continued modernization. Critical to the realization of those objectives are education and language. With regard to language some countries adopted the ideology of "one nation, one language" driven by "a deep-seated fear of linguistic diversity" (Kamwendo, 2013, p. 103). This was buttressed by strong faith in the power of a single indigenous language to facilitate the building of national unity and identity. With regard to education the policy reviews essayed to enhance school performance. In some cases, such as in Tanzania under the leadership of the first president, the late Mwalimu Julius K. Nyerere, there was a fundamental review of the content and overall goals of education in order to counter the basic Eurocentric system of colonial education that had been in place. Like other African languages elsewhere, most of which have yet to even get on the agenda of getting considered for use as LoIs, English is steadily replacing Kiswahili (cf. Bwenge, 2012; Neke, 2003). The salient reason is that English is the language of Science and Technology and of globalization. This chapter examines the connection between language and scientific knowledge with a focus on Mathematics (math) and Science education in Africa. The main thesis is that the appeal to Mathematics and Science education as grounds for the exclusion of African languages as LoIs in education in Africa is simply not defensible; that such exclusion derives from political and economic dependency of African states on European countries, and serves to solidify the "conceptual-cum-linguistic incarceration" of African education.

In the chapter entitled "Global Intersections of English Language Hegemony and Technological Innovation in the Republic of the Philippines" *Brad D. Washington* addresses the perceived necessity of the English language in promoting technological development via the vehicle of STEM education in the Republic of the Philippines. In a nation with over 200 heritage languages, there is an active debate between the preservation of multilingual cultures and histories with the acquisition of English as the prevailing lingua franca of the Philippines. Informed by Filipino communities, universities, and organizations, the chapter explores how conflict, government, and education intersect in documenting how Technology and the English language have been politically intertwined from the mid-20th century to present. In surveying reports by global non-governmental organizations, the chapter presents a framework to consider the inequitable development of education across regions and populations in the Republic of the Philippines in the 21st century. By documenting the voices of educators, researchers, and communities, this study will attempt to increase dialog on how the support of language rights can be a lens into human rights and regional development, especially as it pertains to educational and technological access.

In the chapter entitled "The Importance of Local Language to the Development of Technology" *Basil Okonkwo* argues that in today's world we notice the movement of consumerism and production. Production is a special culture of 'developed nations,' while consumerism is the exclusive culture of 'developing and underdeveloped nations'. It is not surprising that this situation has arisen in our contemporary society. Most countries are dependent on a few nations, which determine the economic strata of the world. Most economies are understood through the examination of the economies on which they depend. This is evidenced by the prices of international commodities such as crude oil, gold and other mineral resources. The cost of these could only be determined by demand of buyers. One begins to wonder why this situation has taken shape in the world. Some people will argue that most developing nations are being exploited and made to solely depend on other nations for aid, support and trade. But this excuse aside, we realize that developing nations are not unique in their cultural and geographical development. Indeed, most developing countries lost their identity to colonialism, but this excuse can no longer hold given that, in most colonized countries, the colonizers have been gone for more than forty years now. The question is 'why the dearth in cultural activity'? In this chapter the author explores the efficacy and indivisibility of language to the development of technology, tests the limitations to the import of language to the development of technology and projects a way forward by making recommendations to future use of local language.

In their chapter entitled "The Issue of English as a Medium of Instruction in Primary Schools in Pakistan: Learning English, Mathematics or Science?" *Abbas Rashid, Irfan Muzaffar, Fatima Dar* and *Salaeya Butt* argue that the Government of Pakistan (GOP) through the National Education Policy (NEP), 2009, made the instruction of English mandatory from class 1 and the MoI for Science and Mathematics from Grade level 4. This chapter deals with the issue of English as the MoI in Pakistan and the readiness of schools and all stakeholders to make this exigent transition. It examines the case of two provinces, Punjab and Sindh and discusses the effectiveness of the MoI policy in the case of Punjab and the readiness of the province of Sindh to undertake the task of teaching English as a subject in public schools from Grade 1 and the MoI in Grade 4. The findings reveal that the teachers' uncertain grasp of English leads to support neither the learning of English, Mathematics nor Science in the classroom—more likely to be achieved through the use of mother tongue, first or proximate language.

The volume ends with *Part IV* – entitled *Human Rights in Mathematics and STEM Education.* The contributions focus on the learning of Mathematics and its learning within the culture. Context matters, therefore through different studies from African and South America, the authors bring another perspective to the learning and teaching of STEM subjects as a human right. The authors argue that inconsistency in programs must be reversed to protect children's rights. Aid programs would be improved through the application of the right based approach to programs involving STEM subjects.

In the chapter entitled "Change in Space, Urban Culture and Ethnomathematics" *Ubiratan D'Ambrosio* points to a strand of Ethnomathematics focusing the State of the World and human occupation and urban culture. The effects of globalization and capitalist greed on the State of the World and the unplanned growth of cities demands a new approach to Mathematics. The author discusses how the Program Ethnomathematics may contribute to the emergence of new approaches to the teaching of Mathematics.

In their chapter entitled "Challenges of Mathematics Education in Multilingual Post-Colonial Context: The Case of Suriname" *Emmanuelle Le Pichon* and *Ellen-Rose Kambel* examine whether the language of assessment influences performance scores of young dual language learners in Mathematics and reading tests in order to determine the role of dual language support at primary school level in Suriname. The objectives of this chapter are to deepen insight into Suriname's linguistic landscape and to emphasize the need for plurilingual and intercultural education. They place the debate in the context of international legal obligations of Suriname which approved the UN Declaration on the Rights of Indigenous Peoples (2007). This declaration includes the right of indigenous peoples to provide education in their own language in accordance with their traditions. Given the current high academic dropout rate in Suriname, in particular in the rural areas, the results informed in this chapter are decidedly relevant. The authors conclude with a discussion of the potential didactic implications of these results for primary education in Suriname.

In his chapter entitled "Why Do Inconsistencies Persist in Children's Rights to 'Good' Education, Heritage Education and STEM Education?" *Ladislaus M. Semali* argues that champions of children's rights emphasize that children everywhere consist of a *vulnerable* age group and therefore, need protections. This chapter speaks for children's rights to "good" education, heritage education and STEM education, and argues that these rights are intertwined with children's health and overall wellbeing. Because young learners are vulnerable and need protections, inconsistencies in Children's Rights to "good" education, directly threaten children's wellbeing and future adult life. Inconsistencies exist when national and global policy statements that advocate for universal education for all children fall short of the political will, budgetary (fiscal) support, and lack system-wide educational planning and evaluation (assessment) of school infrastructure, curriculum in content areas, teaching staff and basic statistics to monitor progress. Consequently, it is imperative to respect and safeguard children's rights against these violations, abuse, or neglect.

In their chapter entitled "Human Rights in Development Aid for STEM Education in Nigerian Languages" *Zehlia Babaci-Wilhite, Macleans A. Geo-JaJa* and *Steve Azaiki* assess the weaknesses in the teaching and learning of STEM subjects, and propose new development approaches to STEM education. By defining access to effective STEM teaching and learning as a right in education, alternative development roadmaps can contribute to both sustainable development and to the satisfaction of the Paris Declaration of Aid Effectiveness. The premise of this chapter is that the right-capability based approach with a focus on human rights will secure best educational practice and insure that education aid systematically ameliorates poverty's multi-dimensionalities. Implicit to this approach is an acknowledgement that African knowledge and African languages are critical to the effectiveness of STEM education. This is demonstrated using Nigeria as a case study. In highlighting roadblocks to human rights of transformational change ownership, the authors recommend that local knowledge and linguistic rights in STEM should be the driving force in development aid and that this should be given the status of a human right in education for sustainable development in Africa.

PART I

HUMAN RIGHTS IN LANGUAGE AND SCIENCE LITERACY

ZEHLIA BABACI-WILHITE

1. THE USE OF LOCAL LANGUAGES FOR EFFECTIVE SCIENCE LITERACY AS A HUMAN RIGHT

INTRODUCTION

The chapter will give attention to several aspects aimed at improving the quality of learning science using local languages in education and local curriculum. The chapter draws on my research on the teaching of science subjects in Zanzibar, Tanzania (The United Republic of Tanzania)[1], South Africa, Nigeria, Norway and the United States, as well as on a review of research on critical issues related to the learning of science that arise from decontextualized teaching and learning in Africa. I will argue that the teaching and learning of science literacy in Africa will be improved through applying a robust theory of inquiry to the learning process.

The teaching of science in Africa suffers from a pedagogy grounded in its colonial history and continued in much of post-WWII development, the stripping of local cultural and natural contexts from science teaching as well as the absence of inquiry-based learning. African countries continue to absorb the standards of the world without the inclusion of local culture in education (Geo-JaJa & Azaiki, 2010; Babaci-Wilhite, 2013a; Okonkwo, 2014). Colonial education in Africa is not transmitting the values and the knowledge of African society from one generation to the next; it has involved a deliberate attempt to change those values and to replace traditional knowledge by the knowledge from a different society. To motivate the active mind, one has to take into consideration the variations in different societies, differences in knowledge and different ways of teaching to achieve quality education. If education is conceived of as imparting knowledge about the world, then schooling should be regarded as only one aspect of education, since it does not cover all forms of knowledge.

Science teaching and learning can benefit from recapturing local language and a pedagogy that emphasizes critical thinking in the search for evidence which provides teachers and students with the capacity to understand and deploy new pedagogical tools for teaching and learning science subjects. Recent studies have shown that students exposed to such models made significantly greater gains based on measures of science understanding, science vocabulary, and science writing (Pearson et al., 2010).

The focus of UNESCO´s Education for All (EFA) initiative has been on basic literacy, stopping short of emphasizing the importance of science literacy in the development of a nation. According to EFA´s global monitoring report, literacy

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skill is more important than ever in today´s knowledge societies, benefiting individuals, communities and nations as a whole. Literacy has been defined as a basic human right, yet in January 2014 the cultural agency of the United Nations issued a report that documented falling education standards around the world. The report pointed out that a quarter of a billion children worldwide are failing to learn basic science principles, creating an education crisis that costs governments $129 billion annually.

Language is central to achieving science literacy and UNESCO (2003) supports mother tongue instruction as a means of improving educational quality by building upon the knowledge and experience of both learners and teachers. Furthermore the support of bilingual and/or multilingual education at all levels of education as a means of promoting equality is a key element of linguistically diverse societies such as most nations in Africa (Skutnabb-Kangas, 2000; UNESCO, 2005; Benson & Kosonen, 2014). Nonetheless, non-localized languages are still chosen as Languages of instruction (LoI) in most African nations' from primary schools through university (Babaci-Wilhite, 2014a, 2014b). Based on my own research and that of many scholars (Pearson et al., 2010; Brock-Utne, 2011; Cervetti et al., 2012), I will argue first that achieving science literacy is much more than rote learning, but rather involves comprehension, the capacity to inquire and to read strategically, and second that use of a local language is critical to access concepts and facilitate deep learning (Cervetti et al., 2006).

The approach I will put forward incorporates the importance of local context in the learning of science, emphasizing the development of local capacity on local terms. This draws heavily on the work of David Pearson (2007) on the important role of language and literacy in the learning of science and in the capacity to think critically and flexibly across many domains of knowledge. In this context Paulo Freire (1970) and his insight that inclusive education, accomplished through the integration of formal and informal knowledge dignifies learners rather than oppressing them. Drawing on the theory of education for self-reliance, developed by Julius Nyerere (1968) and applied in Africa mainly Tanzania, I will argue that education for self-reliance has relevance today in Africa´s efforts to achieve equal access and fairness in education and in the society at large. Finally, I will argue that deep science comprehension is accessible only through the use of a language that students understand best and that science learning in a local language is essential to the achievement of human rights in education (Spreen & Vally, 2006; Babaci-Wilhite, 2012). LoI plays a critical role in cognitive learning and in the development of critical thinking and new knowledge. Drawing on my research in Tanzania, Nigeria and the United States, I will argue that acknowledging local knowledge in educating for science literacy will be a bridge to improve teaching and learning as long as it is contextualized in local languages. This will make a positive contribution to the achievement of quality education in science subjects in Africa.

HOW DO WE ACQUIRE AND IMPROVE SCIENCE LITERACY?

Improving science learning can be addressed by improving literacy, which will facilitate inquiry. Jacqueline Barber (2005) argues that "Inquiry is curiosity-driven… It involves reading books to find out what others have learned… Inquiry requires the use of critical and logical thinking… Good readers inquire information gathered from text." Therefore, Pearson and Barber´s approach to improve literacy through inquiry science engages students in "real-world" interaction to achieve better results for science as well as literacy. This approach resolves the problems of teaching and learning science associated with poorly trained teachers and inadequate teaching aids and facilities. A major challenge in science education is how to support teachers in understanding and enacting inquiry-based instruction. Pearson and Barber in the Seeds of Science/Roots of Reading (S/R) model[2] require teachers to be clear on long-term goals, identify measurable indicators of success, and be accomplished in the practices known to meet the linguistic needs, such as using graphic representations of abstract concepts (Pearson et al., 2013). This fundamental concept builds a curriculum that gives emphasis to literacy through "texts, routines for reading, word-level skills, vocabulary, and comprehension instruction." These work in the service of acquiring the knowledge, skills, and dispositions of inquiry-based science (Cervetti et al., 2012).

Berit Haug and Marianne Ødegaard (2014) described the inquiry-based approach as having "the potential for students to learn how to do science, learn about science, and learn science by doing science." In their study of science teaching in Norway, Haug and Ødegaard (2014) focus specifically on the aspect of "learning science by doing science," which is how to teach for conceptual understanding by emphasizing word knowledge development in an inquiry-based setting. Haug (2014) argues that a call for research on how knowledge is constructed when engaging students in hands-on activities has come up time and again over the past several decades.

Access to literacy must involve making sense of the physical world through first and second hand experiences while addressing foundational dimensions of literacy. Pearson and Barber assembled science and literacy experts to study, enact in the form of curriculum, and test the limits and potential of the science-literacy interface (Pearson et al., 2010). This model of science inquiry involves students in searching for evidence to support their ideas and investigations. Students also engage in critical and logical thinking to learn how to make and revise explanations based on the evidence found. This curriculum addresses the ways that reading, writing, and discourse can be used as tools to support inquiry-based science learning and in which benefits accrue to reading, writing and discourse when they are embedded in inquiry-based science.

The Models designed on the inquiry based-approach has the potential to bring the needed outcomes, results and accomplishments that will improve the process of teaching and learning science. Furthermore Pearson et al. (2013) link their emphasis on existing background knowledge to Goldenberg (2008) who claimed that:

> Beginning reading instruction is guided by neither a theory nor a goal of knowledge development. In fact, just the opposite: children are presented with texts—mostly narrative—chosen to reflect their existing background knowledge, the assumption being that they can use that knowledge to comprehend familiar content.

Goldenberg's point reflects the current situation in Tanzania, Nigeria and other African countries. According to Haug (2014) findings from several studies highlight the importance of the communication and discussion phases of inquiry to foster conceptual understanding in students and stress the importance of the communication phase for learning to take place. They state that to develop understanding of scientific concepts, students must explain and justify their conclusions instead of just presenting their findings as collected evidence. Similarly, Bigozzi et al. (2002) considered the ability to justify data, the most evident feature that distinguishes deep and lasting learning from learning that is purely oral and superficial.

As argued above, engagement with local language and local knowledge is necessary to facilitate the teaching and learning process. Furthermore each outcome in the pathway of change is tied to an intervention, revealing the complex web of activity that is required to bring about change. These principles of learning address the connections between early, intermediate and long-term outcomes and the expectations about how and why the proposed interventions will bring them about (Cervetti et al., 2007). This inquiry based-approach aims for deep conceptual understanding, implementation of a program of planning and evaluation, and a shared cross-disciplinary understanding of the long-term goals and on how they will be reached, as well as what will be used to measure progress along the way.

Improving science literacy in Africa today is mainly done by bringing universal principles to African students through a foreign language and using non-local contextualization and non-local examples (Babaci-Wilhite, 2013a). A model with emphasis on local contextualization, reading comprehension and vocabulary development using a LoI has a great potential to improve science learning. The materials of this model consist of a number of units covering several topics within the different sciences: life science, physical science and earth science. Each unit has a detailed step-by-step teacher's guide describing when to introduce, and how to combine, the different modes of learning (do-talk-read-write). Also included are in-depth science background, instructional suggestions, and statements of what students should master at specific points in the unit, for example, knowing how the targeted scientific concepts interrelate to make meaning.

A multi-modal approach used for example in the S/R model, which provides students with opportunity to access every essential concept to be learned in a unit through a range of different learning modalities. By doing experiences, it engages students in discussing the essential concepts learned and it makes it easy to understand them by reading and enabling students to write them. For instance, for students in coastal areas, they might read about shorelines, then investigate sand, gather evidence from sand and write a text about its properties, which lead to an understanding of the original source of the sand. They discuss their work at regular intervals (in their local language), eventually forming expert groups focusing on particular sand samples. They read about shorelines, then do, then talk, then read again, then do more, then talk, then write, then talk again, then finish what they have written (Barber, 2005). These multiple modalities provide opportunities for students to apply, deepen, and extend their knowledge of the learned concepts.

This effective research-based curriculum offers students an explicit focus on disciplinary literacy and in the specialized knowledge and skills involved in reading, writing, and talking about science. This approach promotes substantive science knowledge through inquiry skills involving students in deep forays into learning about the natural world by searching for evidence through firsthand experiences (hands on activities) and secondhand experiences (text) in order to construct more accurate, nuanced, and complete understandings of the natural world. Furthermore, students engage in written and oral discourse with the goal of communicating and negotiating evidence-based explanations, then evaluate and revise explanations based on that evidence. This is in opposition to the usual approach that simply adds literacy tasks onto a science curriculum, without connecting those additional tasks directly to the advancement of the understanding from the initial investigation and does not provide explicit instruction on how to read and write science text (Pearson et al., 2010). Recent studies have shown that students exposed to the program made significantly greater gains on measures of science understanding, science vocabulary, and science writing (Cervetti et al., 2012).

A curriculum model that links firsthand experiences, discussions, and writing to the ideas and language in informational texts to foster development of core science knowledge and literacy skills is crucial to improving science literacy in Africa, where the contexts of everyday life contrast sharply with the North American and European contexts, where science theory and science curricula are most advanced (Afflerback et al., 2008).

GLOBAL TO LOCAL IMPLEMENTATION OF SCIENCE LITERACY

Around the world, inquiry-based science is recognized in policy documents and curriculum materials as essential to the learning of science; however, research in classrooms indicates that teachers have not fully applied inquiry-based science (Haug, 2014, p. 80). By observing in classroom instructional practices in different phases of science inquiry and the interactions that occurred between teachers and students, Haug (ibid) illuminated different teaching approaches and how they influenced students' conceptual understanding. According to the studies, it is clear that conceptual learning occurs when students are required to apply key concepts in their talk throughout all phases of inquiry, with the students' use of language. In contrast, conceptual understanding is not promoted when teachers do the talking, rephrase students' responses into the correct answer, or fail to address students' everyday perceptions of scientific phenomena. The frameworks applied for word knowledge and link-making are effective in terms of student conceptual learning only if the students are the ones doing the talking and the ones actively engaged in making the links (Haug & Ødegaard, 2014).

Furthermore Haug (2014) argues that when asking Norwegian students in Norwegian schools to apply their new knowledge and think about why it is important to consider when designing new things, nobody responded. She found that students needed clarification and further explanations to develop a higher level of conceptual knowledge. The example shows that knowing the definitions and being able to use science concepts properly in short answers represents only the first step toward conceptual understanding (Bravo et al., 2008). Since reinforcement of new knowledge and development of conceptual understanding typically take place when students discuss their empirical findings and link them to established science, teachers must plan carefully to include enough time for discussion and communication during inquiry-based science instruction.

Pearson et al. (2010) point out the connection between word knowledge and conceptual knowledge by emphasizing that when science words are taught as concepts, applied in a context and in relation to other science words and concepts, word knowledge is consistent with conceptual knowledge. The use of local language and context is critical to learning to use the language of science (Wellington & Osborne, 2001; Barber, 2005). Thus, it is important to emphasize students' development of word knowledge using local language. This application of contextualized science learning through the use of language is consistent with the theories and policies of African education put forward by Nyerere. He insisted on the need for rethinking the relationship between general education and formal education, asserting that the basic system of education, which the Tanzanians took over at the time of independence, should be questioned and the use of an African language should be used in school. His strongly held view was that education must acknowledge local culture, which includes language, social settings and non-material dimensions of life and should be an integral part of daily life, not separated from it. Education should address both the needs of the local people and the country in which they live.

According to Freire (1970), much of the knowledge that forms the basis for schooling has its origins from another place and another time: "Knowledge emerges only through invention and re-invention" (Freire, 1993, p. 53). The students who catch on to this form of learning will be successful in school, but might actually have less knowledge in the broad sense of the word than those who do not attend school. However education is most often equated with schooling (Babaci-Wilhite, 2010). The language issue in Tanzania is deeply related to how one conceptualizes education and the debate around whether or not education should encompass the local cultural context. I agree with Freire (1993) and others scholars such as Hassana Alidou (2003), Martha Qorro (2004), Zubeida Desai (2004), Kwesi-Kwaa Prah (2005), Birgit Brock-Utne (2011) and Jerome Okonkwo (2014) who argue that using a local language as medium of education fosters the broader view of learning which softens the barriers between real-life and classroom experience (Babaci-Wilhite, 2014c). This is consistent with the thinking behind Pearson's approach to literacy that knowledge and wider vocabulary are a consequence as well as a cause of reading comprehension. Therefore the model developed by Pearson and Barber is based on the evidence that language matters and reading comprehension cannot be achieve in a language, which is not mastered by the teacher and the students. There is evidence from several countries around the world that learning through the local languages is the best way to learn science. Most of the countries of Europe and North America teach science in their local language, yet, when it comes to the African contexts, local languages continue to compete with colonial languages in education. It is time for African countries to rethink science literacy using local languages since language is not everything in education, but without language, everything is nothing in education (Wolff, 2006). Thus it can be said that the use of a local language is essential to inquiry-based learning.

LOCAL LANGUAGES AND KNOWEDGE AS A RIGHT TO ACCESS SCIENCE LITERACY

Languages with a colonial legacy, such as English, French, Portuguese and Spanish continue to be used as official languages in many developing countries today. English is a particularly powerful globalizing language that carries with it a cultural context foreign to the local contexts for education (Bamgbose, 2003). Today, English is used as an official or semi-official language in over 60 countries in the world and has a prominent place in a further 20, making it the most learned language in the world (Majhanovich, 2013, 2014). Many language policy makers have adopted this view both in wealthy nations like the United States of America and the United Kingdom, where large amounts of 'foreign aid' money is spent on promoting English, particularly in sub-Saharan Africa where English is now often the sole official LoI at all levels of education in many African countries (Mazrui, 2003).

This language imperialism will need to be arrested if quality learning and science literacy is to be secured. As discussed above, language is the key when it comes to science inquiry. Students gain a better understanding of science concepts when taught through local languages rather than through a foreign language (Brock-Utne, 2012; Babaci-Wilhite, 2015). To develop conceptual knowledge students need help in linking scientific concepts to their everyday experiences, to assimilate new and unfamiliar science words and concepts, and learn how to use concepts in context (Bravo et al., 2008).

In Tanzania, South Africa, Nigeria and elsewhere in Africa, reforms and policies connecting local culture and knowledge to education have been neglected (Babaci-Wilhite, 2015). According to Joel Samoff (2007, p. 60) "effective education reform requires agendas and initiatives with strong local roots" (see also Geo-JaJa, 2013). In other words, local knowledge (also referred to as indigenous knowledge) should be included in the curriculum (Odora, 2002; Babaci-Wilhite & Geo-JaJa, 2011;

Semali et al., 2012). This knowledge should be conveyed in local languages, which is critical to the preservation and development of local knowledge. The choice of the LoI is extremely important not only because of the implications for quality learning, but also because of the intimate ties between language, culture and identity (Brock-Utne, 2012; Babaci-Wilhite, 2013b; Okonkwo, 2014). Local knowledge and languages are being severely strained through globalization, which is a shorthand way of describing the spread and connectedness of production, communication and technologies across the world. We cannot think simplistically about the unidirectional nature of global flows of products and culture, but when it comes to languages there are no doubt that the flow is unidirectional from the Global North to the South. This process has its roots in earlier stages of imperialism and continues to the present (Ngugi wa Thiong'o, 1994; Geo-JaJa & Yang, 2003).

In Africa today, knowledge is equated with what the learner is taught in schools. The knowledge that forms the basis for school curricula is decontextualized. The educated person is one who has mastered sets of facts, propositions, models and cognitive skills that are fundamentally separate from the context in which they were learned. Knowledge is also typically viewed as relatively stable. In mainstream approaches to education, including Africa, schooling often involves the transmission of isolated, portable bodies of knowledge. Schools make sense as institutions only because stable knowledge and reasoning procedures can allegedly transfer and have value in other contexts where students will use the knowledge they learned in school. Because the context is not integral to the knowledge or skill, the isolated "bodies of knowledge" often hold little meaning for anyone other than the members of the community who generated that knowledge. The problems students solve in school are thus problems of the disciplinary communities from which the knowledge originated. This often makes schooled knowledge and skills less useful outside of schools. Moreover, given the decontextualized, insular nature of the knowledge being passed on, there is generally little opportunity for students to question the claims on which the knowledge is based.

Given that most science education in Africa today is neither context sensitive, conducted in language students use to relate to the natural environments nor grounded in an inquiry based curriculum, I argue that the way that science is taught is violating children's rights in education. Article 26 of the United Nations Declaration of Human Rights (1948) states that everyone has the right to education, however it says little about the nature, kind and quality of that education. Rights in education imply that rights are not ensured unless the education offered is of high quality. The rights-based approach is based on the premise that the use of a local curriculum should be regarded as a right in education (Tomasevski, 2006; Babaci-Wilhite & Geo-JaJa, 2014).

Education is an important contributor to human rights effectiveness as it increases human capabilities, functions and opportunities in societies. This further leads to the linkage between human rights and development and enables policy makers and developers to incorporate the "Common Understanding" of a human rights-based approach, assuring these principles: indivisibility, equality, participation and inclusion (UNDP, 2006, pp. 17–18). "Human rights in education" is a powerful notion as it is intimately connected to the social, occupational, political, cultural, religious and artistic life of the people (Babaci-Wilhite et al., 2012; Bostad, 2013). UNESCO's convention on the Protection and Promotion of the Diversity of Cultural Expressions emphasizes the importance of linguistic diversity (2005).

The globalization trends for language in education, in which local curricula are de-contextualized, are in contravention of the tenets of the rights-based approach to language in education. In an increasingly interdependent world it is important to facilitate the mastery of foreign languages as well as mastery of subject matter. The policies for developing countries should also be context sensitive and in addition permit developing countries to remain partners in the global society. Therefore education should be regarded as a set of processes intended to enhance glo-local learning. This is a radical departure from most mainstream educational research and practice, which is designed to enhance global rather than local learning. An innovation to teaching and learning science which couples global developments in science theory with local knowledge, local languages and local teaching can be the bridge to science literacy and to securing African students rights in education.

CONCLUSION

In this chapter, I have reviewed the theory of inquiry relevant to understanding the importance of the use of local languages in the achievement of science literacy. Science cannot be taught without contextualized inquiry. As explained in this chapter when science content is addressed through a combination of inquiry and literacy activities, students learn how to read, write, and talk science simultaneously. These literacy activities support the acquisition of science concepts and inquiry skills. Furthermore the recent studies discussed in this chapter emphasize the connection between word knowledge and conceptual understanding. Therefore the synergy between science and literacy rests upon the understanding that an active level of word knowledge in science (understanding of words as they are situated within a network of other words and ideas) can be described as conceptual knowledge. An inquiry-based model embraces and builds on this science/literacy integration, and especially the connection between word knowledge and conceptual knowledge. As I have argued, conceptual understanding is not promoted when teachers do the talking, rephrase students' responses into the correct answer, or fail to address students' everyday perceptions of scientific phenomena. The frameworks applied for word knowledge and link making are effective in terms of student conceptual learning only if the students are doing the talking and are actively engaged in making the links. Therefore in order to enable inquiry, African languages need to be valued and preserved. This will facilitate the learning process and support students in their preparation to engage with the world in their own terms.

There is ample evidence that embracing local context through the use of local language in an inquiry-based approach leads to improved literacy, scientific knowledge, and personal efficacy for students and greater professional efficacy for teachers. I recommend mapping African teachers' ideas and thoughts regarding science inquiry and their view on their own level of content knowledge. This research would examine the whole inquiry cycle in different stages and how this could be planned for and utilized in teaching. This would allow teachers to engage students in discussions that build on evidence collected through investigation and to be more aware of what to look for in student responses and how to act upon these to promote conceptual understanding. This implies more research from African classrooms on how to conduct science inquiry in ways that enhance student learning. This model, emphasizing the local context and using a local language, will contribute to rights in education and to children's engagement in science subjects for quality education.

NOTES

1. Tanganyika gained its independence from Britain; and Zanzibar became independent in 1963. On 26 April 1964, Tanganyika joined with Zanzibar to form a new state, now named the United Republic of Tanzania.
2. The S/R model was co-founded by Professor David Pearson and Jacqueline Barber at the Lawrence Hall of Science (UC-Berkeley) California. This model is a primary curriculum that supports teaching in which students learn science concepts in depth simultaneously as they are taught how to read, write, and discuss through inquiry-based science.

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