TACKLING EDUCATIONAL QUALITY AND EPISTEMOLOGICAL ACCESS CONCERNS IN SCIENCE AND TECHNOLOGY EDUCATION IN AFRICA: THE "LEARNING-AS-CONNECTION" IMPERATIVE.

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Abstract

The main purpose of this paper is to catalyse debates on educational quality and relevance in the Africa science and technology education context. It seeks to show that poor educational quality developed via science and technology education is a manifestation of poor facilitation of epistemological access. The curriculum is not contextualised adequately and largely lacks in inclusivity with respect to local examples and cultures that may inform pedagogy. It proposes the adoption of learning as connection discourse. This discourse developed in the context of educational research case studies in southern Africa scopes learning as actively interfacing context and concept. It stresses the need to make connections to social-cultural, socio-ecological, and to personal, familial and other real life situations in the community. More importantly, learning as connection facilitates and reinforces epistemological access and learning for sustainable development in and through science and technology education.

***Key words*:** educational quality, epistemological access, education for sustainable development (ESD), science education, sustainable development

1. LEARNING FOR SUSTAINABLE DEVELOPMENT AND THE AFRICAN DREAM

Learning for sustainable development is a global notion (UNESCO, 2016) that is the ultimate outcome pursued in all learning areas including Science and Technology Education. The failure to pursue and achieve this lofty educational agenda in Science and Technology Education amounts to a failure of the African dream of sustainable development. This African dream is expressed in the first speech delivered by the President Kwame Nkrumah (the president of the first country in Africa to gain independence from British colonial rule in 1957) at the foundation summit of the Organization of African Unity, Addis Ababa, on 24 May 1963 (now Africa Union).

> "We shall accumulate machinery and establish steel works, iron foundries and factories; we shall link the various states of our continent with communications; we shall astound the world with our hydroelectric power; we shall drain marshes and

> swamps, clear infested areas, feed the undernourished, and rid our people of parasites and disease. It is within the possibility of science and technology to make even the Sahara bloom into a vast field with verdant vegetation for agricultural and industrial developments" (Ghanaweb, 2013).

This dream reverberates today in *Agenda 2063: The Africa we want* (Africa Union, 2015). Learning for sustainable development is critical to the development of African nations. In this vein the Africa Union articulates the pertinence of educating for sustainable development when it states that:

> "Education is a critical sector whose performance directly affects and even determines the quality and magnitude of Africa's development. It is the most important means we have at our disposal to develop human resources, impart appropriate skills, knowledge and attitudes. Education forms the basis for developing innovation, science and technology in order to harness our resources, industrialise, and participate in global knowledge economy and for Africa to take its rightful place in the global community. It is also the means by which Africa will entrench a culture of peace, gender equality and positive African values" (Africa Union, 2006 at www.nepad.org).

Science and Technology Education and sustainable development have a relationship of interdependence that predicates learning for sustainable development. Through Science Studies at every level of an education system, students ought to get an education for sustainable development. We base this assertion cognizant of the richly philosophic notion of "Education through Science" (Holbrook, Rannikmae & Valdmann, 2014). This notion encompasses intellectual understanding of the nature of Science in a manner and extent that links it (i) to the achievement of goals in the personal domain, (ii) to the promotion of character and positive attitudes, and (iii) to achievement of goals in the social education domain, including socio-scientific decision-making. The concept of 'Education through Science' thus reminds us that the "over-riding target for Science teaching in school, as an aspect of relevant education, is seen in responsible citizenry, based on enhancing scientific and technological literacy." Clearly, social and humanistic goals cannot be outside the realm and pedagogical discourse of Science Studies whether at the school level or at the tertiary level, and attending to these humanistic and social goals might be the defining elements of educational quality and relevance.

This becomes immensely relevant in the African context where by historical and colonial precedent there exists a disconnect between knowledge circulating in the education system and that relevant to the life and well-being of individuals and their communities (Lotz-Sisitka, 2008; Shumba, Kasembe, Mukundu, & Muzenda, 2008) and the disjuncture between scientific and everyday ways of knowing (Shumba, 1999). This disconnect can be seen in the lack of

genuine personalization of meaning in terms of utilizing the knowledge, skills, and values in Science Studies to improve personal well-being. It is in the decontextualised curriculum in which local examples and case studies are under-represented or excluded that this can be seen. There is a disconnect seen in the non-reference to valuable indigenous ways of knowing, indigenous explanatory frameworks, indigenous practices and technologies, and most importantly, exclusion of the value ethics of the African, *Ubuntu* and in my language *Unhu*. Overall, we find in this situation that the knowledge that circulates in the education system is not sufficiently connected to learners' backgrounds, experiences, and cultures with great implications for quality and relevance, especially in Science and Technology Education. Its tendency is exclusionary.

2. LEARNING DISCONNECT AND NATIONS AT RISK

The questions of contextualization and relevance in Science Education and especially, if we seek to transform our ways of thinking, doing and being necessary for sustainable development, need serious interrogation. The following is a demonstrative quote of the untenable situations of lack of socio-cultural and personal significance and relevance, and signification.

It is a fact that despite the wide spread of science in the educational system, most Africans including professors of science, scientists, and technologist still hold strongly to the belief in black magic, mysticism and superstition. Again, most of our scientists including professors cannot translate most western concepts and generalizations in science to African cultural or traditional application. This can be seen in the inability of our scientists to translate what chlorophyll and photosynthesis are in their native dialect. This raises a serious question on thought pattern or reasoning. Do Africans especially the scientists; think in their native language or in English or in French?" (Usuquo, Samuel, Bassey & Bassey, 2010).

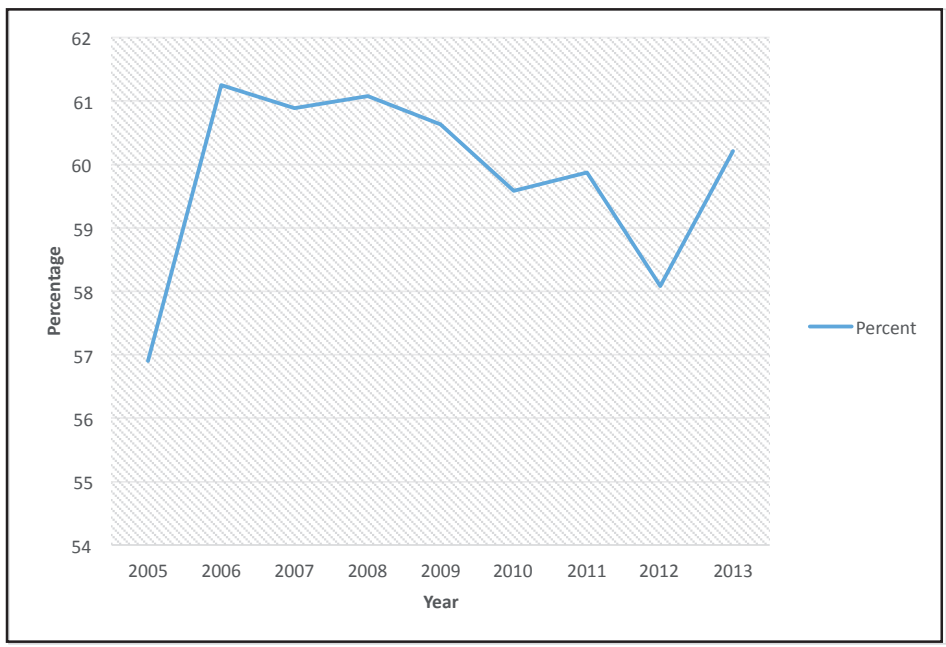
The above scenario reflects some anecdotal evidence of the learning disconnect and its consequences at the level of professionals in science. It has nothing to do with being African, but rather it reflects deeper epistemological disconnections evident in the imagery of "hazardous" cultural border crossings (Aikenhead, 1996; 2001; 2007) and parallel collateral learning (Jegede, 1995). This status and lack of conflation between western and indigenous knowledge systems creates conditions that not only endanger quality of Science and Technology Education, but also the pursuit and attainment of sustainable development. Many countries in Africa, as revealed by reports of various examination boards, show an imperilled state of academic achievement, the worst results in test scores and literacy levels being associated with Natural Science subjects. In Zambia, the *First National Assessment Project* (ECZ, 1999) stated that Zambia is "a nation at risk" (p. 6) and it went on to observe, "… levels of learning achievement are low right across the country, in all grades and in all curriculum areas. Very little learning of the type expected by society is occurring in

Zambia's schools" (p. 6). Learners from countries such as South Africa that participate in the TIMSS, PIRLS and SACMEQ perform poorly relative to learners from comparison countries outside Africa (Spaull, 2013). Numerous reports from the Examinations Council of Zambia (ECZ) paint a startling picture of secondary school students' academic achievement in, especially, Mathematics and the Natural Sciences (ECZ, 2014 & 2015, Kiwala, Nachibanga & Macwani, 2016). In 2013, the candidates obtaining a full certificate at the GCE O level represented 60.21% and the percentage of students obtaining full certificates has been hovering around the same percentage since 2006 (Table 1 and Figure 1).

Table 1: *National trends in candidates obtaining school certificates 2005-2013.*

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Percentage	56.90	61.25	60.89	61.08	60.63	59.58	59.87	58.08	60.21

Figure 1: National trends in candidates obtaining school certificate 2005-2013



Source: Examination Council of Zambia, 2013

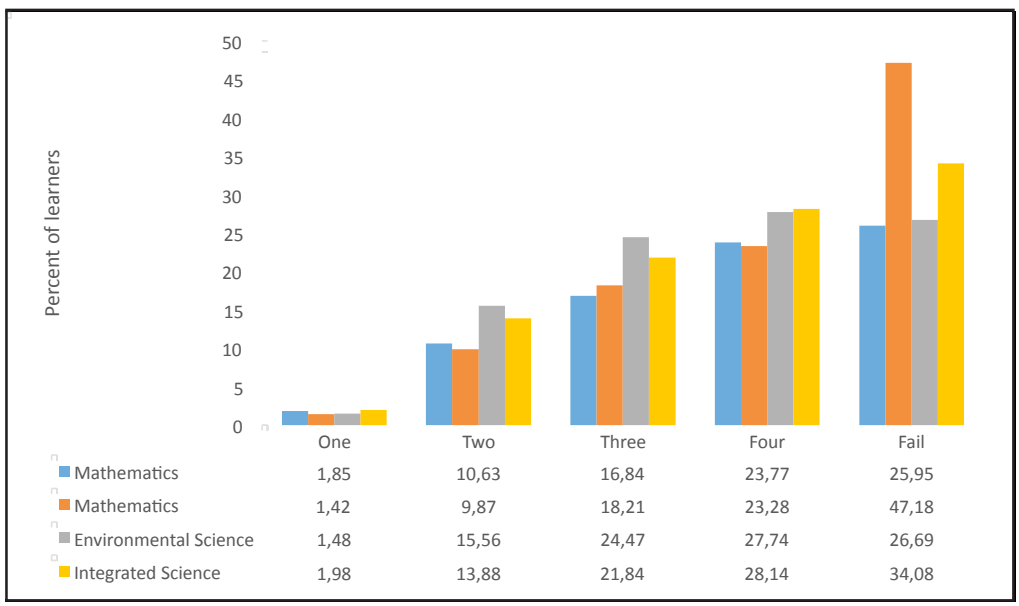
Some of those who fail to obtain full certificates can be traced to the low level of passes and failure rates in the Natural Science subjects in grade nine examinations (Table 2 and Figure 2). Around 50% either got grade four or completely failed the 2013 grade nine examinations in Mathematics and Environmental Science. In 2015, the situation got worse where 47.18% failed Mathematics completely and 23.28% got a grade four result. In Integrated Science (in the new curriculum), 34.08% obtained a failed result in 2015 compared to 26.69% who previously failed Environmental Science in 2013. This reflects a decline in achievement at this level.

Table 2: *Grade 9 subject grade distribution for science subjects in 2013 and 2015.*

Subject	**Year**	**Grade Scored and Percent %**				
		One	Two	Three	Four	Fail
Mathematics	2013	1.85	10.63	16.84	23.77	25.95
	2015	1.42	9.87	18.21	23.28	47.18
Environmental Science	2013	1.48	15.56	24.47	27.74	26.69
Integrated Science	2015	1.98	13.88	21.84	28.14	34.08

Source: Examination Council of Zambia (2014)

Figure 2. *Grade 9 subject grade distribution for science subjects in 2013 and 2015.*

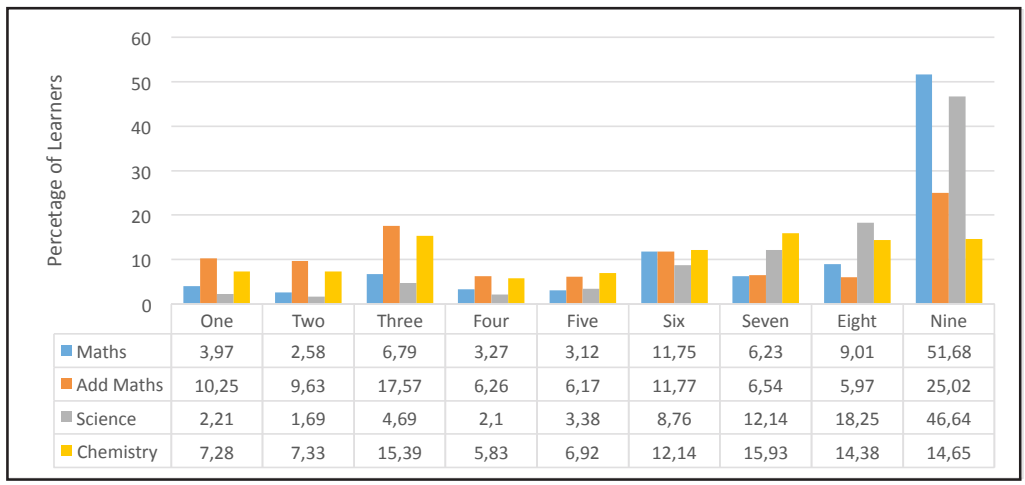


Let us also peek at the situation at the end of the secondary school cycle where the majority of students take Mathematics syllabus D and Science 5124. In 2014, over fifty percent (i.e., 51.68%) got a failing grade in Mathematics and 46.64% in Science (Table 3 and Figure 3). The same trend is seen in Table 4 and Figure 5 where the 2015 results show that 50.6% got grade nine in Mathematics and 48.6% got a failing grade in Science 5124, marking an increased failure rate. The results for "pure" Chemistry 5070 like other "pure" Sciences and Additional Mathematics show lower failure rates (e.g., 14.65% for Chemistry 5070) as these subjects are taken by the most able and academically talented but these are in the minority.

***Table 3**. Extract of Grade 12 subject grade distribution for selected Natural Science subjects in 2014.*

Subject/Grade	One	Two	Three	Four	Five	Six	Seven	Eight	Nine
1. Maths	3.97	2.58	6.79	3.27	3.12	11.75	6.23	9.01	51.68
2. Add Maths	10.25	9.63	17.57	6.26	6.17	11.77	6.54	5.97	25.02
3. Science	2.21	1.69	4.69	2.10	3.38	8.76	12.14	18.25	46.64
4. Chemistry	7.28	7.33	15.39	5.83	6.92	12.14	15.93	14.38	14.65

***Figure 3**: Extract of Grade 12 subject grade distribution for selected Natural Science subjects in 2014.*



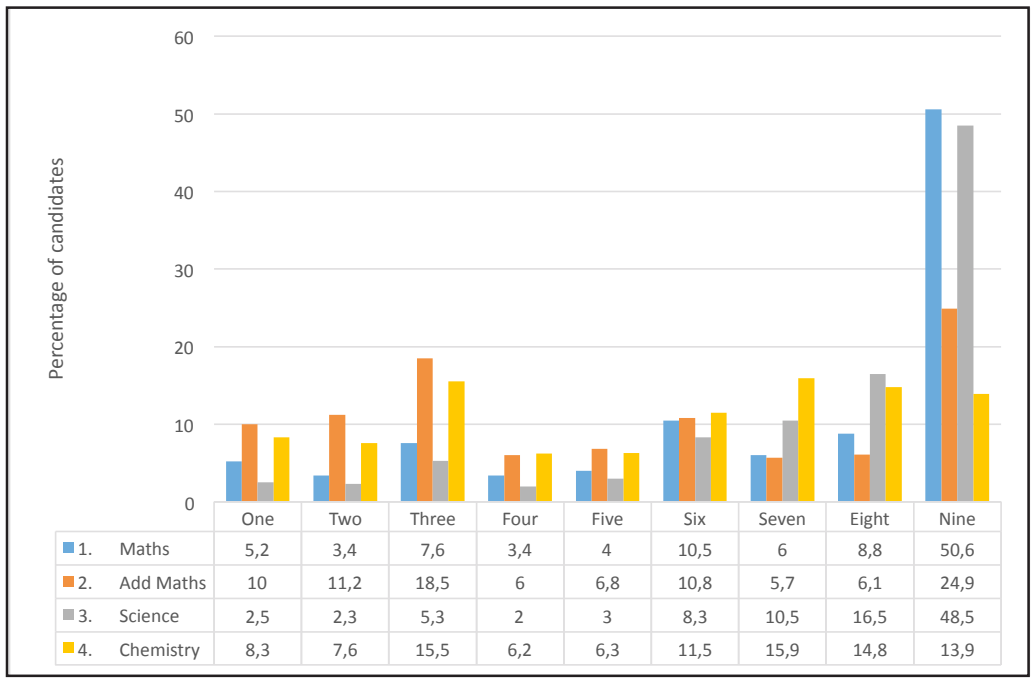
Source: ECZ, 2015

Table 4: *Extract of Grade 12 subject grade distribution for selected Natural Science subjects in 2015.*

Subject/Grade	One	Two	Three	Four	Five	Six	Seven	Eight	Nine
1. Maths	5.2	3.4	7.6	3.4	4.0	10.5	6.0	8.8	50.6
2. Add Maths	10.0	11.2	18.5	6.0	6.8	10.8	5.7	6.1	24.9
3. Science	2.5	2.3	5.3	2.0	3.0	8.3	10.5	16.5	48.5
4. Chemistry	8.3	7.6	15.5	6.2	6.3	11.5	15.9	14.8	13.9

Source: Extracted from Kiwala, Nachibinga and Macwani (2016).

Figure 4: *Extract of Grade 12 subject grade distribution for selected Natural Science subjects in 2015.*



Source: Extracted from Kiwala, Nachibinga and Macwani (2016).

Clearly, these data point to an imperilled Science and Technology education landscape, at least in one country in Africa. African countries that participate in international comparison of achievement in Mathematics and Science have generally ranked behind comparison countries outside

Africa (Spaull, 2013). Many factors account for the state of affairs, not least among which are the learning disconnect referred to above. We do concede that the examination results as presented above can only be a proxy for gauging educational quality in a system. We are mindful of the multiplicity of factors that may equally explain some aspects of educational quality. For example, it is typical that we point to the qualification of teachers, the availability of resources such as textbooks, apparatus, and laboratory reagents, and many other material grounds. The learning disconnect as we see it is cognitive rather than material-resource linked. The disconnect relates to the factors that are intellectual and epistemological, i.e., knowledge-oriented, and those factors that would shape the intellectual environment, what knowledge is found in the curriculum and what ways this knowledge in the curriculum is transacted and negotiated, and meaningfully assimilated to become part of who we are as scholars of science. These are some epistemological access factors, of which we can also identify a basketful of them. The inadequate (even denial of) epistemological access could explain the state of academic learning and achievement in the Natural Sciences in schools and undergraduate studies. We contend that full epistemological access is the *sine qua non* of educational quality.

3. EPISTEMOLOGICAL ACCESS *SINE QUA NON* OF EDUCATIONAL QUALITY

Arbee, Hugo and Thomson (2014) (citing Morrow, 2003 and Gee, 2005) explain the concept of epistemological access in relation to the ability to understand and 'own' both the knowledge and the characteristic ways of knowing, and ways of being associated with particular academic disciplines. Ultimately, to achieve full epistemological access entails that students be able to appreciate the appropriate identity of a discipline (what we may call the discipline-centric view). In science education, this would mean students have to appreciate the nature of science, for example. Taking Chemistry as an example, this would entail understanding the transformation of substance and materials, how to explain behaviour of these transformations using appropriate models and theories, using acceptable chemistry language and IUPAC nomenclature and conventions, how to represent the substrates and products symbolically and by equations.

We contend that epistemological access is more than this. It entails (or ought to entail) too an understanding of the applications and impacts of chemical technologies and products, personally and in society. For example, Lotz-Sisitka (2009) argues the need to go beyond the technical and discipline-centred approach to teaching and learning and to "embrace an open-ended notion of epistemological access to enhance reflexivity, agency and responsiveness to risk and vulnerability" (p. 11) associated with, for example, risks and vulnerability posed by climate change, biodiversity loss, HIV-AIDS, Ebola, and other such conditions. Does this not need or require a different pedagogical orientation? Is it not a different type of understanding and a different kind of pedagogy when students are asked to reflect in Chemistry and make

the connection, for example, when they respond to the following as citizens and consumers? For example, should the Bonn-Haber process developed in the context of providing ammonium nitrate fertilizer to boost crop production and fight hunger have been the driving force behind the war machines around the world?. At the personal level, how much do our household chemical products contribute to the pollution load of the local water bodies and to the cost of water processed by the water utility company? What are the implications for biodiversity? What do the pollutants contribute to the cost of potable water? What is the level of awareness concerning consumer products, e.g., improper dumping of household chemical products? Do they understand that the use of chemical products may be an expression of lifestyles, e.g., cosmetic practice of skin lightening with hydroquinone skin breaching creams? In addition to students of Science studies having complete access to the knowledge and ways of knowing and being in a discipline they must as well have complete access to the social, economic, cultural and ethical dimensions or implication of the subject. For further reflections on the relevance and case studies of epistemological access in, for example, Physics, Life Sciences, and Anatomy (Bozalek, Garraway & McKenna, 2011).

4. EDUCATIONAL QUALITY, EPISTEMOLOGICAL ACCESS AND INCLUSIVITY

The question of educational quality in Science Education is a question of epistemological access, which in our opinion has not been given due consideration in Science curriculum and instruction. Some of our pedagogical actions limit epistemological access starting as early is in Basic and Secondary Education levels. These are sites where the spirit of scientific inquiry together with critical questioning must be nurtured and yet they can be places that dissuade and suffocate critical questioning and inquisitiveness. One example suffices. It is the story of the Tanzanian pupil Erasto B. Mpemba who in 1963 discovered an important phenomenon that remains unexplained today, the *Mpemba effect,* later published in the journal *Physics Education* in 1969.

The Mpemba effect relates to the observation that hot water can sometimes freeze faster than cold water, but which has not yet been explained. Erasto had asked his physics teacher (who dismissed him as confused) why the ice cream mixture he had been boiling had frozen quicker than that of his friend which had been more tepid. It is reported in the *Science Magpie* that towards the end of June 2012, the Royal Society of Chemistry created a competition to find the best explanation of the Mpemba effect. In the case of Mpemba, we can blame it on teachers who suppress the spirit of questioning and inquisitiveness, a common problem across Africa. This behaviour illustrates an example of an epistemological factor that shapes the pedagogical space in Science Education by denying students to question and wonder. This can easily shape what we students believe to be the nature of science, that is, delivered by authorities, factual and unquestionable and that the role

of students is that of receptacles and receivers of given information.

The decontextualized curriculum also limits the extent of epistemological access. While various efforts at localising the Science curricula in Africa have been undertaken, the persisting resemblance of these curricula to the curriculum models of former colonizing countries' universities and examination boards is usually easy to notice. These tended (and tend) to be formalist, content-, object-, and process-oriented, while in contrast African education (built on *Ubuntu* philosophy and values) differs markedly by tending to be humanistic and values-oriented. This leads, in the context of Science education, to a situation where learners fail to conceptually connect content of school subjects to their personal lives in the community. This creates conditions of "hazardous" cultural border crossings (Aikenhead, 1996) and parallel collateral learning (Jegede, 1995) and an uneconomic way of learning. The above scenarios, coupled with the failure to contextualize the curriculum by bringing in local examples and practices, lead to a decontextualized learning space where students might learn in the classroom about the structure of a hibiscus flower and not relate it to any other flower in the local environment.

The differences in the indigenous ways of thinking and knowing and the 'scientific' ways of thinking and knowing in the Science classroom, coupled with the decontextualized learning space they create, make the personalization of meaning difficult, if not completely impossible. This decontextualisation leads to the curriculum irrelevance of "school Science" that immensely hampers full epistemological access. 'School Science' is coined from Whitty's (1985) notion of "school knowledge," by which he means a selection of knowledge that is carved "from a much vaster range of knowledge" (p. 1). This Natural Science knowledge in the curriculum in much of Africa does not account for indigenous knowledge or indigenous natural science, and examples drawn from local environments. For example, the ethno-chemical knowledge of the African concerning mineral ore extraction of iron and copper, the fermentation process in brewing, *kachasu or munkoyo* and the souring of milk, the use of fire and ashen to neutralize the acid soils, e.g., in *chitemene*, the case of many ethno-medicinal practices, and so forth, that is, the knowledge excluded in the Science curriculum. One cannot cease to think too of the Physics teacher attempting to bring an understanding of the electrostatic explanation of thunder and lightning in the village where local belief holds that certain people have powers to capture and use their potent force to attack enemies. One wonders too concerning the belief among many peasant farmers in African communities that the use of chemical fertilizers will kill the crop. This is the reason studies acknowledge that "no community, even at its most traditional level, exists in a 'knowledge-vacuum' and any sustained capacity can only be built if the transferred knowledge is intertwined with the positive fabrics of existing local knowledge systems" (World Bank, 2000).

The above background suggests the need for seeking pedagogical models that

are transformative in being inclusive and that we need to question Science Education and Technology Education built on the culture deficit assumptions. Pedagogical models that are inclusive are more likely to result in Science and Technology Education that is seen as relevant at the personal, familial and societal levels. This is the rationality of the 'science-technology-society' (STS) approach stressing connections and applications in Science and Technology Education in the 1990s. The STS approach was meant to provide opportunities for students to tackle problems of local interests and personal impact, careers in Science and Technology, and to make the learners see the importance and relevance of Science and Technology knowledge as useful and needed to solve problems in daily life. The STS approach is a clear effort to balance the interests of all by ensuring relevance at the personal and societal level. Psychologically, this touches the personal psyche and provides the motivation and drive for a learner to engage, to focus, to strive, to persevere, and possibly to succeed in Science Education.

5. EPISTEMOLOGICAL ACCESS, INCLUSIVITY AND LEARNING FOR SUSTAINABLE DEVELOPMENT

Above, it has been shorn how a learning disconnect can lead to a nation at risk and how a decontextualized and non-inclusive learning space stifles epistemological access in Science and Technology Education. It has been shown that an approach such as the STS approach attempts substantially to cater for personal and societal relevance, and thus for learners in Science to approach socio-scientific issues and other humanistic concerns. It is relevant to connect this to the earlier reference to the African dream, of sustainable development driven by science and technology. This requires a strategic re-orientation of educational processes to achieve 'learning for sustainable development' (UNESCO, 2016). This kind of learning goes beyond simple transfer of knowledge; it seeks to make learners into persons who can make decisions and act based on the knowledge they acquire (Fritjers, 2016). As stressed by Arjen Wals, learning for sustainability is transformative and it "emphasises 'learning for being", alongside learning for knowing and learning for doing" (Wals, 2010, p. 32). As such, learning for sustainable development is more than gaining of knowledge, values and theories related to sustainable development. Education for Sustainable Development (ESD) learning also refers to learning to ask critical questions; learning to clarify one's own values; learning to envision more positive and sustainable futures; learning to think systemically; learning to respond through applied learning; and learning to explore the dialectic between tradition and innovation (Tilbury, 2010). In learning for sustainable development, the pillars of quality learning (UNESCO, 1996 & 2010) remain relevant, inter alia:

- *Learning to know*- entails acquisition of instruments of understanding and finding out, or learning how to learn.
- *Learning to do*- entails application of learned knowledge in everyday life to act creatively and responsibly. Learning

involves learner questioning of and engagement with local sustainability practices.

- *Learning to be*- entails the development of the whole person, including personality, self-identity, self-knowledge, self-fulfilment, etcetera in a lifelong learning process.
- *Learning to live together*- entails changing one's lifestyle, having respectful relationships and respecting the rights of others, valuing difference and diversity, valuing social inclusion, conflict resolution, and mutual understanding. Learning includes consideration and questioning of equity, fairness and social justice in distribution of resources and opportunities within and between generations.
- *Learn to transform oneself and society*- entails being self-critical and having knowledge, values and skills to change one's lifestyle and serve as an agent of change for a sustainable future. This includes competencies and abilities to reflect on, and act together with, others to learn from sustainability practices and to change unsustainable practices.

An education through Science and Technology Studies requires that these learning outcomes be achieved. It is worth noticing from this that Science and Technology Education faces serious challenges requiring us to think deeply and creatively about educational quality and relevance and frameworks to guide us to think and reflect about them. For example, Professor Arjen Wals (2010) of the Wageningen University, Netherlands, made the proposal that we need forms of education and learning that can develop capacities and qualities of individuals, groups and communities to meet the challenges of sustainability. Such forms of learning are more than knowledge-based; they focus on existentially relevant 'real issues' to engage learners. Such forms of learning consider learning as cross-boundary in nature and permitting "increased permeability between units, disciplines, generations, cultures, institutions, sectors, and so on" (Wals, 2010; p. 22) which in turn require the "competence to integrate, connect, confront, and reconcile multiple ways of looking at the world" (p. 32). As can be seen from our reflections here, we need to engage in debates concerning educational quality and relevance in order to tackle the intellectual and epistemological disconnect found in Science and Technology if we do nothing.

6. EPISTEMOLOGICAL ACCESS AND EDUCATION FOR SUSTAINABLE DEVELOPMENT

In southern Africa we have pondered since 2007 how this may be achieved, framing our educational research network's thinking and practices around the notion of 'learning-as-connection' (Lotz-Sisitka, 2010; Lupele & Lotz-Sisitka, 2012; Lotz-Sisitka, 2012/2013). This powerful notion emerged from a series of ESD case studies[1].

[1]The network initiated with seed funds from the Southern Africa Development Community Regional Environmental Education Programme (SADC REEP, 2008-2012) is coordinated by Professor Heila Lotz-Sisitka, Murray and Roberts Chair in Environmental Education at Rhodes University. It involves institutions from Botswana (University of Botswana), Lesotho (Lesotho College of Education), Mauritius (Mauritius Institute of Education), Mozambique

The case studies explored the question: What contribution does education for sustainable development make to debates about educational quality and relevance? Illustrative case studies focused on various facets of learning for sustainable development and the following examples suffice to show some of the issues explored:

- contextualized and problem-based learning approaches in the curriculum in general (Bholah, 2012; Shumba, Kasembe, Mukundu, & Muzenda, 2008);
- integrating Environmental and Science Education in education in particular (Monjane, 2017; Shumba & Kampamba, 2012/13); and
- cultural artefacts and indigenous knowledge in the curriculum (Namafe, 2008; Namafe & Chileshe, 2012/2013).

(Pedagogical University of Mozambique), Namibia (University of Namibia), South Africa (Rhodes University), Swaziland (University of Swaziland), Zambia (University of Zambia & Copperbelt University) and Zimbabwe (University of Zimbabwe)

The results of the case studies inspired the evolution of the concept of 'learning-as-connection' and the books *Learning Today for Tomorrow: Sustainable Development Learning Processes in Sub-Saharan Africa* (Lotz-Sisitka & Lupele, 2012) and *Education for Sustainable Development and Schooling in Africa* (edited by Wilmot, Lotz-Sisitka, Shumba, & Lupele, 2017). With respect to Science Education, we have explored how the notion of learning as connection can lead to a balanced treatment of disciplinary knowledge, socio-ecological issues and other humanistic concerns in Science Education (Shumba, 2012; Shumba & Kampamba, 2012/13; Shumba & Kampamba, 2017) and proposed pedagogical innovations and transformative pedagogies in Science Education (Shumba, Kasali, Choobe, Mutondo, Maseka, and Mbewe, 2016)). Overall, we argue for a framework and an approach of integrating and connecting the scientific and technological content of curriculum and change projects to real life contexts, including social contexts. For example, we argue the need to gain scientific knowledge of, for example, climate change science, should not be the end all of learning in Science Education (Shumba, et al, 2016). Learning must include an understanding of the development issues associated with climate change and an appreciation of practical ways to act and do things to cope with or mitigate its impacts.

A reflective change in the pedagogical content knowledge of Science and Technology educators premised on the notion of ESD pedagogical content knowledge (ESD PCK) was postulated (Shumba & Kampamba, 2012/13). The ESD PCK foregrounds the relevance of understanding ESD concepts, principles, and values (i.e. ESD content knowledge), and the appropriate teaching and learning approaches with which to interrogate and act on them (i.e., the ESD pedagogy). Therefore, ESD PCK relates to teacher expertise to connect subject content and concepts to issues of concern to society's development. This ability to tackle the universal concepts of science and contextualise them to local real-life issues and problems will lead to attainment of 21st century learning outcomes. This is defensible if we take de Jong's (2005) suggestion that an education in science should develop capabilities to form opinions and make political decisions on science-technology-society issues. We see science education as a knowledge area and a process that is beneficial to society, and as such, it must take its full share of responsibility for educating for sustainability thinking and action. For this to happen, social and humanistic issues in the sustainable development discourse must not remain at the periphery of science and technology learning.

7. EPISTEMOLOGICAL ACCESS AND LEARNING AS CONNECTION

Clearly, what we suggest in the above is to ensure the complete 'connect' among learning a discipline and relevance in real-life contexts and problem-solving. It reflects the learning as connection principle. The notion of 'learning as connection', is part of the discourse of educational quality that views learning as actively interfacing context and concept and thus making connections to social-cultural, socio-ecological, and to personal and communal life-worlds and experiences (Lotz-Sisitka, 2008; 2009; 2010; Lotz-Sisitka & Lupele, 2012). Learning as connection advocates for education to be connected to socio-cultural, contextual and historical dynamics of learners' life worlds and experiences, while simultaneously gaining mastery of educational concepts and content. Therefore, learning as connection provides for contextualized and locally referenced approaches to quality in science and technology education (Shumba, 2012).

Learning as connection entails a deep engagement and participatory discourse of educational quality. It is important for learners to engage with questions that may have wider implications for learning for sustainable development. In the context, of chemistry education, it is relevant, for example, to allow students at the same time to reflect on social issues of consumption and the ethics of production as they learn the cannons of chemical knowledge. For example, should the Bonn-Haber process developed in the context of providing ammonium nitrate fertilizer to boost crop production and fight hunger have been the driving force behind the war machines around the world?. At the personal level, how much do our household chemical products contribute to the pollution load of the local water bodies and to the cost of

water processed by the water utility company? What are the implications for biodiversity? What do the pollutants contribute to the cost of potable water? What is the level of awareness concerning consumer products, for example, improper dumping of household chemical products? Do they understand that the use of chemical products may be an expression of lifestyles, for instance, cosmetic practice of skin lightening with hydroquinone skin breaching creams? Such questions are relevant in learning for sustainable development and for developing a value ethic relevant for us and our students to engage in debates and actions towards sustainable futures.

8. SUMMARY AND CONCLUSION

What this paper has shown is the fact that the African dream of science and technology-driven sustainable development is far from reached. A large impediment can be found in the poor educational quality developed via science and technology education. The curriculum is not adequately contextualised and largely lacks inclusivity with respect to local examples and cultures that may inform pedagogy. The paper has shown the risks of poor learning achievement to nations and their sustainable development. It is desirable to transform and remove barriers to epistemological access that are the sine qua non of educational quality. We have proposed a learning-as-connection framework in which conceptions of quality education are three-fold and intersecting. They entail (i) an efficiency/mastery discourse leading to a view of learning as mastery, (ii) an inclusivity/participatory discourse leading to a view of learning as participation, and (iii) a 'learning as connection' discourse (Lotz-Sisitka, 2008; Lupele & Lotz-Sisitka, 2012; Lotz-Sisitka, 2012/13). In the latter discourse of educational quality, learning is featured as actively interfacing context and concept and thus making connections to social-cultural, socio-ecological, and to personal and communal life-worlds and experiences (Lotz-Sisitka, 2008). Meaning-making that occurs at the interface of existing experience and context leads to more abstract forms of representation and comprehension.

Therefore, learning-as-connection as observed in Lotz-Sisitka (2012/2013) "further deepens notions of inclusivity or inclusivity concepts of quality so as to be inclusive of culture, local context and issues, and practices that have meaning in local societies, such as environment and sustainability practices, health education practices, life skills, and citizenship practices". The learning-as-connection discourse expresses, therefore, the relationship between meaning-making, context, and concept which creates deeper understanding. Taking Lotz-Sisitka's example, teaching and learning fermentation (concept) may best be facilitated by reference to the local beverage brewing process (context). In this example, the concept of fermentation and the context (local brewing process) interface to facilitate meaningful and connected learning. Everyday knowledge, concepts and experience are brought into relationship with scientific and abstracted representation of knowledge, concepts and societal experience (Daniels, 2002 cited in Lotz-Sisitka,

2012/13). In our view, learning-as-connection fosters epistemological access and potently transforms quality and relevance of science and technology education.

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