African Condition and the Changing Goals of Science and Technology Education

Silas Oluka
DOSATE
Makerere University

Abstract
The paper explores the evolution of science in Africa against the perceived policy emphasis of role of science and technology (S&T) in development. The deployment of science and technology in the school curricula, and the question of relevance are debated with guiding questions such as: *Who* and *what* shapes science and technology discourse in school science? What frame of S&T best promotes development in Africa? The presentation examines a range of factors, issues and arguments in science and technology education in Africa, and proposes possible future trajectories of science and technology education.

Science in Africa

Africa is the only major region of the world that has thus far failed to achieve a significant measure of sustainable human development. The results of this failure have been: civil wars, political instability, authoritarian regimes, widespread violation of human rights, unacceptable level of poverty, widening gap between Africa and the developed world, and increasing marginalization of the continent in an increasingly interdependent world.

Although there is no consensus on an 'optimal' strategy for the successful management of Africa's development crisis, it is widely agreed that investments in people and in science and technology are prerequisites for achieving significant economic growth and social transformation.
Available data show that Africa's stock of human capital is particularly poor, and the science and technology base in Africa is conspicuously weak. These two crucial dimensions of development have been pushed aside by the imperatives of 'crisis management' that has characterized the continent's political and economic policies.

The need for investing in science and technology (S&T) in Africa is predicated on the urgent necessity of equipping the continent's labour force with the skills and competencies associated with numeracy as well as with the advanced S&T research knowledge and skills required by a global knowledge-driven economy. Africa can ill-afford to ignore the importance of S&T for today's and future society that is perhaps best captured by Alfred N. Whitehead insightful observation, made more than 50 years ago, that if civilization continues to advance in the two thousand years, the overwhelming novelty in human thought will be the dominance of S&T thinking. It is no coincidence thus that worldwide, S&T are advocated as prerequisite for modernization and economic development. Countries recognise importance of STE and demonstrate their trust in S&T policy provisions that prioritise these subjects and or integrate them across national curricula. But has STE delivered on the claims of modernisation? What has been its impact?

Science in Africa: its evolution

Developments in science and technology have had profound effects on humankind, even in the Africa region. These effects are not limited to the quality of lives, but extend to the ways people think about themselves and others, and in their expectations concerning the future ways of life. S&T increasing play a political role in African society that may often miss recognition. Similarly, it is easy to take for granted the S&T dominated increase in the quality of lives in African communities. To illustrate this, we can consider life in Africa four centuries ago, say in the 1600s. In Europe, this epoch occasioned great explorations, cultural awakening, of Copernicus and the birth of modern science. In Africa, the *mfekane*[1], migration, tribal wars, and a range of other challenges were widespread. Life was a hazardous enterprise played out as an exercise in survival often in the locality of one's birth; with disease, pestilence and famine as constant threats to survival. Owing to low populations at the time, infant mortality rates and life expectancy leave a lot to imagination. Epidemics such as the plague were common. Information about people was only passed from generation to generation using the best technology then: oral tradition. Until the mid 1900s, nature dominated African society as it had for all previous ages. There was little to delight in about nature, and little sense about what Francis Bacon foresaw in Europe as the *power over nature* that would come with the use of modern science and technology. People in Africa lived according cultural norms.

Colonisation wars of the 19th century, and the subsequent formation of states gave little attention to STE. In the 1950s-60s, few schools taught biology, chemistry and physics; on the main, curriculum was racially defined and or gendered. In the early 1960s, the awakening to STE was triggered by the states' thrust for independence. An primary school level, science existed as nature study, hygiene, health and rural science. The focus was on rural life for African children. In the few urban schools serving the predominantly white and some elite (including Asian families), objectives for teaching science were not stated as the focus was on overseas exams, such as the Cambridge Examination Certificates in secondary level.

The African Primary Science Programme (APSP) for the mainly British aligned states such as Kenya, Ghana, South Africa, Zimbabwe, Zambia, Malawi, Uganda, and Nigeria started with missionary influence and participation of scientists from the US and Britain in 1960. The APSP, the African Science Programme (SEPA) and Nuffield Secondary School Science, the Namutamba Project in Uganda by UESCO (1967) and the Entebbe Mathematics programmes of the latter part of 1960 and early 70s facilitated science educators into inquiry-based teaching and learning of science with the hope of inspiring some creativity in the learners and innovativeness among the teachers. The impact of these science programmes was limited by inadequacy of facilities, the resourcing of education in general, including the competencies of the science and mathematics teachers themselves, particularly for schools serving African children.

[1] A Zulu word for (times of) tribulations, social unrest, particularly triggered by the murderous rule of Shaka Zulu and his expansionist rule in South Africa.

In the last two decades, Africa has seen a re-emergence of great interest and support for science and technology education (STE). Such initiatives such as the African Forum for Children's Literacy in Science and Technology (AFCLIST), funded by Rockefeller Foundation and NORAD; the Zanzibar camps, the Minds across programme (Uganda), the Science Curriculum Initiative in South Africa and a range of other S&T projects such as NUFU Basic Science Project (1991-2006) of Makerere University, among many others in the sub-Sahara Africa region. A characteristic of these projects is their central focus on the despair of the challenges of transforming science teaching for the better. This interest hinges on a number of basic principles for changing STE: a need for systemic change, which focuses on human development; orienting STE to local realities such that curricula, teaching materials, and assessment process should be contextual and ensure sustainability. The notion of *context* in STE is geared towards evolving a critical mass of S&T human capital. These demand that STE be inquiry-based, and focus on scientific skill development. Science and technology teacher education should also address and alter the classroom power relations that make learning collaborative, inclusive, and less authoritarian. This is expected to accommodate heretofore excluded groups, especially the girl-child and other socio-economically marginal groups.

Role of S&T in Development

Development is an ideological concept. However, the different interpretations share in common the perception that significant economic growth is a prerequisite for development. And whereas there is no consensus among economists as to the mix of elements that would cause growth, it is widely accepted that such a mix would necessarily include investments in people and in science and technology (S&T).

Many economists argue that human capital in the form of educational attainment plays an important role in economic growth (see for example: Schultz, 1961; Denison, 1962; Lucas, 1988; Mulligan and Sala-I-Martin, 1992). Empirical studies of Peaslee (1965, 1969) and Benavot (1985) demonstrate that primary education had a significant positive effect on economic growth of both industrialized and developing countries. A World Bank study of East Asian 'miracle' countries shows that "the single most important factor in launching the miracle countries on a path of rapid, sustained economic growth was universal or near-universal primary school enrollment" (World Bank, 1995; p.34). In the case of South Korea, Soh (1992; p. 163) found that in support of economic development "Korean education supplied various types of manpower needed for national economic growth, with education given credit for as much as 22.61% of the increase in the country's gross national product over the 1984 – 1986 period." More recently, Goldsbrough (1996; p.86) studied the impact of adjustment policies on growth in eight developing economies and concluded that "the two most important variables contributing to growth are investment in physical capital and the achievement of basic educational achievement, as measured by primary school enrollment ratios."

In a recent influential empirical study, Barro and Lee (1993) present a data set on educational attainment for 129 countries over five – year periods from 1960 to 1985. In this study, human capital is the number of years of completed schooling for persons aged

25 and over. Barro and Lee show that for developing countries as a whole the average of school attainment doubled over the period (from 1.8 years in 1960 to 3.7 years in 1985), while that in SSA grew by 80% (from 1.5 years to 2.7 years). The results further show that while SSA has made significant achievements at all three levels of education, about half of the adult population in 1985 received no formal education.

How has Africa's stock of human capital evolved since 1985? Adult illiteracy rates may be used to proxy for the no-schooling category. The illiteracy rate for the population aged 15 and over in Africa is 45.6% in 1995, with Uganda's corresponding share being 64%, which is more than double the corresponding rate for Latin America and the Caribbean (UNESCO 1999).

School enrollment ratios provide information about flows of education, and the accumulation of these flows is a principal component in the creation of stocks of human capital in the future. Although Uganda has made some progress in all levels of education in the last five years – four decades after independence – sustaining the attained levels of access to primary, secondary and tertiary education poses a serious challenge in a national budget being financed at more than 50% on donor support.

Of 13 African countries for which data comparable to that of Barro and Lee are available, only 4 have improved the composition of their respective stock of human capital relative to that of SSA in 1985. These countries are: Botswana, Mauritius, South Africa, and Zimbabwe. It is interesting to note that the first 3 of these 4 countries have higher than average GNP per capita in Africa. However, since economic activity is influenced by, among other things, "the knowledge, skills, competencies and other attributes embodied in individuals" (OECD 1998:9), it is important to consider qualitative aspects of human capital.

Research results show that school quality is an important determinant of pupil achievement in developing countries. In particular, instructional facilities and materials, teachers and textbooks appear to be critical variables. See, for example, Husen et al. (1978), Heyneman et al. (1981, 1983), Fuller (1987), Cope (1989).

Issues in S&T Education

The state of S&T education and S&T research in Africa is particularly grave. Teachers of S&T are both under-qualified and poorly motivated; S&T curriculum reform is often inspired by uncritically imported western models; examinations determine the 'worth of S&T knowledge'; memorization and rote learning are the dominant forms of teaching; and the subject's unity and links to science and technology and relevance to student's everyday experience are hardly emphasized. There is less inquiry science learning, more rote learning. Children are less, than more, able to extract meaning from their schooling for relevant application.

There appears to be an assumption that quality teaching is provided and assured by curriculum (read *content*) changes.

This has tended to create a temporary, and false comfort in education delivery, assessment, and management. In the desire to provide quality science education, educators and all the other stakeholders should grapple with the questions as to where quality rests. Is quality in: the national education policies? Is it in curriculum documents? assessment process? What *truly* benchmarks quality and relevance in STE? With present resurgence of long-standing concern about education of scientists and engineers, compulsory sciences in schools and about public understanding of science and technology, the public is pointing to the “failure” of STE curriculum development. There is advocacy for preparation of “up-to-date’ text materials, hoping that this time the materials will be “relevant,” “better” and “more effective.” Is this the case? Very unlikely, for many reasons, e.g.: curricular materials, however lucid, skillful, and imaginative, cannot “teach themselves.” The most significant cause of failure in adoption and implementation of better STE curricula materials lies in what happens in science teacher education and their professional development. A teacher can always negate the intent of the S&T materials by attitude, unpleasant comment, and, most significantly, by what he or she chooses to test for. Another formidable obstacle that must be overcome at all levels in the schools is that of logistic support.

There are a number of consequences of these and other state-based and institutionally intrinsic limitations in STE. For example, in Makerere University, only about 10% of the cross section of university students execute *thinking*, *reasoning*, and *understanding*, indicating that they have developed the capacity for abstract logical reasoning at this rudimentary level; up to 60% or more of the students are unsuccessful in the tasks and still use predominantly concrete patterns of reasoning; the remaining 25% are in transition, exhibiting only partial success; most university students are very much in need of practice in the various modes of *thinking* and *reasoning* in S&T. Sometimes the volume and pace of material thrust on students in the majority of S&T courses preclude the exercise of the time-consuming operations of thinking, reasoning, and understanding. The majority of students are thus forced into blind memorization, and they eventually come to see all “knowledge” and “understanding” as the juxtaposition of memorized formulae, names and phrases. They are tested almost exclusively on the memorized end-results. Makerere University students’ evaluations, based on administration of two or more of the now classic Piagentian tasks, are showing, with remarkable reproducibility, important data for debates on STE curriculum reform (Oluka, 2006). On a wider Africa frame, about 40% of Africa’s 151 universities do not have a department of S&T; the Bachelor’s degree programs in S&T is unpopular among students and are least subscribed to; undergraduate S&T curricula of many departments emphasize traditional areas of the subject; and the demand for graduate education in S&T in most African countries remains limited. This is an education that would not suit an industrial age, let alone an information age society. As such the current status of S&T in education badly fails Africa’s youth upon whom the continent’s future depends. We need genuine understanding of basic concepts that can perfectly well be developed in elementary and secondary school, and enhancement of capacities for abstract logical reasoning at secondary and university levels as important ingredients to accompany STE curriculum reform. In this framework, students would enter post-primary with levels of knowledge and understanding that would make discussion of philosophical, historical, ethical, and societal questions fruitful and meaningful. They would be able to penetrate aspects of modern S&T that are now hopelessly unintelligible. With such improved background in S&T, our mass production system of lecturing to large classes might be substantially more effective, if still not ideal. Such progress is impeded at the present time, not b.y lack of adequate curricular materials at elementary, secondary or tertiary levels, but by inadequate teacher education in the sciences.

The standard approach adopted by most African countries, including Uganda, for developing S&T human capital is to send students for postgraduate studies in S&T in western countries. This approach is expensive, risky, and ignores the fact that S&T research and S&T education are organically linked: a weakness in either will undermine the other as well as the S&T base itself. Studying S&T in an industrialized context raises questions of relevance to the localization of the knowledge and skills gained to one's context back home in Africa. In order for Africa to be able to come to grips with its serious difficulties and to meet the challenges of the future, it must urgently develop strategies that would significantly enhance the quality of her human capital and strengthen her S&T base. Given the nature of the unfolding future (sustainability, equity, respect of human life and harmony in diversity), it should be evident that any nation that does not strive for excellence in education, in general, and in S&T, in particular, would do so to her own peril.

Rethinking STE: Who shapes the discourse on science and technology education?

As Volnick (1998) critically observes, dominant trends in various aspects of science and technology education in African nations are shaped and determined by particular interest groups with conscious or unconscious agendas. As social constructs, discourses are roles that govern how to create meaning and ascribe value. Two key players in the S and T discourse environment are teachers and learners.

Ideologically, a scientific and technological world – view is guided by need to classify, label, asses and measure all that is animate and inanimate. In this regard, S&T are driven by a desire to control and dominate. It is for this reason that critics of science and technology, like Feyerabend (1981) and Longino (1993)see S&T as divorcing fact from value in favour of fact, leading to devaluation and marginalization of people and to the creation of otherness. In Adas's view, (1989) science and technology are uncritical adoptions of dominantly western views, technologies and methods.

The analytical criticism of S&T: in relation to what is included and excluded: what S&T discourse render marginal, render inferior, and make invisible, calls for critical reflection. It is this process of reflection that will generate opportunities for the two key players in STE: the teachers and learners, to recognize the delicate connections between all humanity, S&T and our environment, and to identify the various forces and relations that prevent us from optimally benefiting from the complex web of interconnectivity and interdependence of life.

In the context of education practice, policy and priorities, what is of concern in African context relates to who is involved in S&T education, who directs its goals and activities, and whose interests the S&T education discourse perpetuates.

As Ernest (1991) has documented, there are multiple interest groups in society with contending ideologies to an S&T curriculum. In an emerging paradigm shift from S&T for career to S&T for all, the current arguments in S&T education calls for openness to possibilities of discourse that embraces the complexity of issues that humanity faces in the contemporary world.

Making science relevant implies:

- Experiential learning is of prime importance
- Learning is contextualized within the local realities.

Ogunnyi (1985) decried the continued regression of science education in Africa. When we extrapolate his concerns of almost two decades ago to the current situation, we note that the general poor performance is S&T has further disturbing characteristics of boys, girls, race and socio-economic variations, with concerns about relevance, academic rather than applicable knowledge and skills focus..

Significance of S&T education stretches beyond the honoured objective of white-collar career paths. The brazen inequity, coupled with irrelevance, stifled economic and social potential for all strata of our society call for holistic approaches that take into consideration the individual, society, family, learning institution, and the workplace.

A common feature in STE in African nations includes large, overcrowded, and poorly resourced classes. This further compounds the challenges faced in realizing effective science discourse.

In constructing a relevant S&T in Africa, conflicting views in need of reflection include:

- What counts as science?
- Whose knowledge?
- Science and indigenous knowledge?

S&T teachers need new, innovative and holistically conceived avenues for their personal and professional growth if they are to revitalize their teaching, increase laboratory based participatory learning and research experience in their classrooms as well as their capacities to communicate the exciting application of science to their students and fellow teachers.

Conclusion: How do we change?

The science, technology and society movement of the last two decades has generated interest and flexibility in S&T curricula to accommodate varying views and interests both socially and educationally. The matter of overwhelming endemic dominance of positivist motions of science, guided by a strict adherence to positivism regarding the methods of science call for adjustment to accommodate emerging philosophies about knowledge and learning. As Loving (1995), Jegede, (1995; 1994) have argued, science and technology are now increasingly seen as evolving ways of coping with the world within specific contexts and cultures. Sensitivity to these contexts and cultures demand responsiveness of S&T discourse to alternative world views: a disentanglement from defensive, mainstream western science. Similarly, as Jegede (1990) and Lee (2007) put it, consideration of science as per interpretations within indigenous action aligns STE with the tenets of educating for sustainable development. Four principles are implied here. First, STE should be biographically contextual, embracing change and transformation of the status quo, because the existing education systems in Africa support the reproduction of dominant social practices and ideologies which need to be questioned and challenged if the transmission of unsustainable systems and ways of life has to be checked. Second, STE should engender critical thinking so that questions about which S&T, S&T for what purposes and interests, alongside the examination and questioning of roots of unsustainability in the society are critically addressed. Third, STE should embody holistic approaches to accommodate the broad, complex interconnections between science, technology, society and development. This interconnectivity requires an all round understanding and dialogue to make STE future-oriented, with a long-term perspective because STE should equally be concerned about long term survival. Fourth, STE should embrace international understanding and global citizenship by integrally addressing globalisation issues that affect all humanity. Such an outlook should expose learners to global issues and problems of S&T and development beyond the confines of national agendas of economy, society and ecology to include problems of hunger, poverty, water, HIV/AIDS, pollution, nuclear power problems and how these affect us all.

In Africa, for S&T to be seen as ways for society to understand and relate to the natural environment, their study will need to be integrated with the world outside the learning space of a classroom to acknowledge the existence of two world views and to try to integrate them so that a common explanation and meaning of S&T becomes possible. These considerations have major implications on curriculum review, packaging and implementation. Science teachers as facilitators in S&T discourse need well conceptualized and articulated teacher education programmes that assure coherence between goals and needs of holistic STE.

References

Adas, M. (1989) machines as the measures of men: Science, Technology and Ideologies of Western Dominance Ithaca, NY: Cornell University Press.

Barro, Robert J. and Lee Jong-Wha (1993). International comparisons of educational attainment. Journal of Monetary Economics 32, 363 – 394.

Benavot, Aaron (1985). Education and Economic Development in the Modern World. Ph.D. diss., Stanford University, Stanford, Calif.

Cope, Janer, Carmelle Denning, and Lucie Ribeiro (1989). Content Analysis of Reading and Mathematics Textbooks in Fifteen Developing Countries. London: Book Development Council. Processed.

Denison, Edward F. (1962). The Source of Economic Growth in the United States and the Alternatives before Us, New York: Committee for Economic Development.

Ernest, P. (1991). The Philosophy of Mathematics Education, London: Palrer Press.

Feyerabend; P. (1981). How to defend society against science. In scientific revolution. Ian Hacking (ed). Oxford University Press.

Goldsbrough, David et al (1996). Reinvigorating Growth in Developing Countries: Lessons from Adjustment Policies in Eight Economies. Washington: IMF Occasional paper 139.

Heyneman, Stephan P., Farrel, and Manuel A. Sepulveda-Stuardo (1981). Textbooks and achievement in developing countries: What we know. J. Curriculum Studies 13 (3), 227 – 46.

Heyneman, Stephan P., and William A. Loxley (1983). The effect of primary school quality on academic achievement across twenty-one high and low income countries. The American J. Sociology 88 (6), 1162 – 94.

Husen, Torsten, Lawrence J. Saha, and Richard Noonan (1978). Teacher Training and Student Achievement in Less Developed Countries. World Bank Staff Working Paper 310. Washington, D.C.

Lee, S. 2007. A conceptual framework for education for sustainable development in Asian context. A paper presented in a Workshop on Human Rirhts and Peace Education for Teachers in Uganda. Kampala: Korean National Commission for UNESCO & Uganda National Commission for UNESCO.

Longino H. (1993). Subjects, power and knowledge. Description and prescription in feminist philosophies of science. In Alcott, L. & Potter, E. (ed.) Feminist epistemologies, pp. 101 – 20. New York: Routledge.

Lucas, R.E. (1988). On the mechanics of economic development. Journal of Monetary Economics 22, 3-42.

Mulligan, C. and X. Sala-I-Martin (1992). Two capital goods models of economic growth. Unpublished paper (Yale University, New Have, CT.).

Oguminyi (1986) two decades of science education in Africa science education 70 (2) 111 – 22.

Oluka, S (2006). Technology in science classrooms: enhancing student active science. In Press.

Peaslee, Alexander L. (1965). Elementary education as a pre-requisite for economic growth. International Development Review 7, 19-24.

_______ (1969). Education’s role in development. Economic Development and Cultural Change 11 (3), 293 – 318.

Schultz, Theodore W. (1961). Investment in human capital. American Economic Review 51 (1), 1 – 17.

UNESCO (1978 – 79, 1988, 1992, 1994, 1995, 1996, 1998, 1999): Statistical Yearbook.

World Bank (1995). The East Asian Miracle: Economic Growth and Public Policy. New York, N.Y.: Oxford University Press.