2. The Contribution of Science and Technology

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Technological dependence lies at the heart of all dependencies. Therefore, we in the developing countries should evolve a technological capacity appropriate for our own conditions; select technologies and adapt them to our own economic and social infrastructures in the context of our own culture and way of life.

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What Science and Technology?

Before the 1300s, Europe was not and had never been the most powerful and advanced society in the world. Two centuries later, Europe's dominance was firmly established – a dominance largely due to the rise of science and technology. Since then, by comparison with the non-industrialised countries, developed countries have enjoyed unprecedented levels of socio-economic growth, recently accelerated by the development of information technology. At a time of talk of the global village, despite being blessed with natural resources, most of Africa remains entrenched in millions of isolated rural villages scattered throughout the continent, and the gap between industrial and non-industrial countries widens increasingly rapidly. Many external factors have contributed to this crisis, such as slavery, colonialism and economic imperialism. However, some factors are internal, such as corruption and poor governance. Though poverty is the most visible symptom of such societies, another major underlying cause of poverty is the mindset that has characterised village societies throughout history. Common attributes of the village mindset include:

- A deep-rooted conservatism that clings firmly to the traditional ways that by definition have enabled the village to survive;
- A similarly deep-rooted suspicion of external influences that so often have destabilised the status quo;
- A strong commitment to the authoritarian, patriarchal power structures that maintain village cultures.

AFCLIST believes that modernisation in Africa must be viewed through the lens of this rural village mindset, and must be based on development of the continent's human as well as its natural resources. Only when Africa institutionalises innovation can the countries of sub-Saharan Africa join the global rather than the rural village mindset that for aeons has absorbed outside influences as the body absorbs food that in some cases is digested to make the body stronger and at other times makes the body sick, but never changes it in any basic way. The rural village is sustainable in a physical, though undoubtedly basic, sense and consumes outside influences, be it Coca-Cola, modern drugs, Kalashnikovs or schooling, in the same way as it absorbs its food. But there is a critical difference. The food eaten in the rural village is prepared by cooks from the village, but the Coke, Panado, arms and knowledge are always prepared far from the village and even from the nation. It has been argued that information technology is the 'magic bullet' that will transform rural Africa. But unless the basic village mindset also changes, the 'magic bullet' will turn out to be as effective a tool as the 'magic water' that 'protected' Africa's warriors from the real bullets of the Lee Enfield and Maxim guns of the colonial powers. AFCLIST strongly believes that appropriate science and technology education can play a significant role in fundamentally changing this village mindset. AFCLIST believes science and technology education can do so because the disciplines:

- Constantly innovate, and use tradition only as a stepping stone to new knowledge and not to preserve the status quo;
- Welcome, rather than suspect, outside influences because they can lead to new understanding;
- Favour an open and questioning mindset that is committed to developing, rather than maintaining, society and that has strong implications for better governance than that to which Africa and the world are accustomed.

The science and technology that AFCLIST promotes is not the knowledge or products of the disciplines that are currently taught for students to consume. AFCLIST is emphatic that it is inquiry science, or the mindset of the knowledge production processes of science and technology, that the young people of the continent must learn if Africa is to leapfrog from the rural village into the global village. In making this jump, information technology becomes an additional intellectual tool to be used just like any other intellectual scientific tool rather than yet another gadget to be switched on like a television set.

There are several implications in adopting the knowledge production approach of science and technology education that AFCLIST promotes, with its implicit assumption of problem identification and solving. These include the assumption that the educational process involved is:

- Relevant since the problems are, for the most part, those in the learners' environment rather than those in the textbook;
- Economically feasible since the local problems identified are solved using locally available resources and not some unavailable (because of the expense) piece of equipment such as a Wheatsone Bridge;
- Culturally appropriate since the learning takes place within the learners' experience and not within the context of the textbook or standard laboratory.

That science and technology would bring development became a mantra in many countries of sub-Saharan Africa immediately after independence. As Yoloye (1998) and Reddy (1998) report, regional and national policy statements such as the Lagos Plan of Action (1980) and the African Priority Programme for Economic Recovery (1986) repeatedly stated government intentions to support science and technology. Despite such declarations, Ghana and Uganda, for example, in 1993 only spent 0.08 per cent and 0.06 per cent of government expenditure on research and development. Important as levels of funding are, what science and technology should Africa pursue? As Borja asks, what science and technologies are appropriate? Which should Africa select? And how should we adapt them to our own contexts?

Makhurane and Kahn (1998) and Naidoo and Savage (1998) suggest a need in Africa for a targeted practice of research science. Africa's comparative advantage is limited to a few fields such as cosmology where the University of Cape Town is a recognised authority on the southern sky. Africa, however, has pressing needs to which research science can contribute, such as the breakthroughs in root crops and pest control made by international research centres such as the International Institute for Tropical Agriculture (IITA) in Nigeria and the International Institute for Insect Physiology and Entomology (ICIPE) in Kenya. It is inappropriate for most individual countries in sub-Saharan Africa to support research science that is costly and that, for the most part, can only duplicate research elsewhere. The funding that is available for such research may be better used to support international centres that could become centres for high-level training and co-ordination of national research. Makhurane and Kahn (1998) recognise a need for some research in Africa '... that pushes back the frontiers of knowledge' for the inspiration that its intellectual integrity gives to those working in the more directly relevant fields of applied science. They also suggest subscribing to journals, attending specialised meetings and exchange programmes as alternative ways that scientists practising applied science can keep in contact with the cutting edge.

Chapter 5 provides examples of how top research scientists have popularised the practice of research science and technology by demonstrating their relevance to everyday problems. In Kumasi, Ghana, the University of Science and Technology supports workers in the agricultural, informal and formal sectors who are attempting to solve local problems. The work of Dr Emmanuel Fabiano extends over some six years in Malawi. His research, in collaboration with university and industrial scientists in Canada and industrialists and young university researchers in Malawi, has led to plans for a factory that will manufacture a variety of products from cassava (see Chapter 4). South Africa has mapped its future route for science and technology and has identified its basic strategic science and technology needs, such as research in biotechnology to support its wine and fruit juice industry. But Africa still has a need for basic as well as applied sciences.

Makhurane and Kahn (1998) define applied science as that which '...enables people to add value to their resources, is itself problem-solving in its execution, and blurs distinctions between science, technology and, on occasion, sociology'. They cite agricultural extension work with farmers, university consultancy centres and health extension work as good examples of the practice of applied science needed by Africa. Educational systems in countries of sub-Saharan Africa could learn from their style of work. Schools are the most widely distributed educational institutions in Africa, yet they rarely serve as resources for local communities. Chapters 2 and 3 describe examples of primary schools, secondary schools and tertiary institutions working to bridge school science and technology and that practised in the community.

There is considerable debate about the universality of science. Some, like Jegede (1998), take a constructivist view of knowledge and argue that there is a 'Western Science', an 'African Science', a 'Japanese Science' and so on arising from the different cultural contexts. Others, such as Makhurane and Kahn (1998), take '... a rationalistic view of science as a culture that may be superimposed on any culture since it is universal, and a culture of hope and undying optimism'. However, there is less debate about the universality of technology. Technology is practised in every community in Africa, ranging from the technology of the traditional herbalist whose knowledge of plants is extensive to that of the roadside mechanic whose tinkering genius keeps vehicles on the road long past the time they would have been scrapped in any industrialised society. It is, however, fruitless to encourage Africa to chose between indigenous technology and Western science. Only a judicious balance between the two can bring the economic development for which the peoples of sub-Saharan Africa hope.

We see little need to discuss the science and technology normally taught in schools. We are all only too familiar with a subject that bears no resemblance to research science, applied science or that practised in the community. Most school science has little relevance other than being necessary to pass examinations, and it is little wonder that it has failed to bring the hoped for economic and social benefits. Subsequent chapters will illustrate what science and technology we think should be popularised to achieve these goals.

Popularising Science and Technology

Yoloye (1998) reports on some of the many regional conferences that in the early 1960s stressed the importance of science and technology education to economic development in Africa. These include the 1961 Addis Ababa Conference of African States on the Development of Education in Africa, and the 1962 Conference of Ministers of Education on the Development of Higher Education in Africa, held in Tananarive, Madagascar. The recommendations of such meetings became a guideline for many countries of sub-Saharan Africa. Science and technology appear on primary school syllabuses of most Anglophone countries of English-speaking Africa. Yoloye quotes World Bank studies as claiming that in 1993 Nigeria spent 200 per cent of the subsidy to general secondary schools on agricultural schools and 125 per cent on industrial schools. Countries such as Nigeria have almost achieved the 60:40 ratio for science admissions to university recommended at Tananarive (Fabiano, 1998).

What science education?

Traditional science education has failed to make the contribution to development for which Africa hopes. Despite the overall bleakness, however, there is considerable evidence that more appropriate science education can not only develop the skilled human resources necessary for economic development, but also the critical skills and values needed for good governance.

Jegede argues that '... the knowledge base for schooling should draw from traditional and current beliefs, taboos, superstitions, customs and traditions'. His position is strongly supported by constructivist theories of learning, as well as by good classroom practice in Africa and elsewhere. Harris (Commonwealth Secretariat) quotes studies in India by Passi that '... through a locally developed curriculum ... placed in a non-formal, learner friendly environment, girls, rural learners and members of scheduled castes and scheduled tribes performed at comparable levels to, and sometimes better than, their upper caste and urban counterparts'. Chapter 4 describes examples such as the

'Linking Community with School Science' project in Malawi that do so. This multimedia project has developed resource materials for teacher education. The opening videotape shows interviews with village craftspersons. Subsequent tapes show primary school pupils being taught in a way that uses that community knowledge. A project in Zimbabwe first interviewed primary school pupils about their understanding of syllabus topics before developing learning materials in mathematics and science. 'Thinking Science' in Malawi is a secondary school project based on the same assumption that students must actively reconstruct their own meanings for true learning to take place. Its effectiveness can be measured by the superior external examination results of students involved in the project, not only in the sciences, but also in languages and mathematics (Mbano, 1998).

There are other reasons for using community knowledge of science and technology as a base to teach school science. Fabiano (1998) pleads that, 'The immediate school environment and community are rich but often neglected resources for science and technology teaching. Ignoring them and ignoring the knowledge base of communities in Africa increases the costs of supporting learning.' Savage (1998) describes how in Kenya, the tutor of a teachers' advisory centre made extensive use of local resources. He helped pupils in one primary school to set up a community science museum from which teachers could borrow teaching aids. Pupils turned another school into a factory for producing tools. A third became a soil conservation centre that mapped friable soil sites. Parents could buy horticultural seeds, grasses, multipurpose trees and ornamental shrubs from the school-based centre. Using local resources can considerably reduce the costs of science teaching. Doing so also brings community knowledge of technology to the attempt to solve problems in schools and takes universal knowledge of technology from schools to solve problems in the community.

Rollnick (1998) argues '... in African classrooms, where science education is not only irrelevant ... its very irrelevance is considered a virtue ... Irrelevance affects quality of life and the ability of students to control their lives'. Use of the local environment and knowledge base to teach school science not only makes learning more accessible and meaningful, it can also add to community knowledge by helping solve local problems. Chapter 12 describes the work of Andrew Nchesi, a primary school teacher in Malawi, whose pupils have won many national and international awards, and whose teaching has the full support of parents and the community. Often his pupils' research is directly relevant to village life and has including designing fuel-conserving stoves, the use of alternative fuels from refuse such as maize cobs and charcoal water-evaporating cooling boxes. 'The Water Project' in South Africa has designed simple kits that enable children to monitor local water supplies and provides scientific evidence when they complain to the appropriate authorities.

Reddy (1998) reports that 'In the Sudan, 80 per cent of urban, but only 20 per cent of rural, children go to school'. She quotes International Council of Education Development estimates that only 50 per cent of school-going rural children in most countries complete four or more grades. Reddy reports Odaga and Henneveld (1995) as estimating that in Africa in 1990, girls made 45 per cent of primary, 40 per cent of the secondary school and only 31 per cent of the tertiary level population; participation rates in the sciences were even lower. In Zambia, a lack of school space denies access to formal education to 45 per cent of seven-year-olds, and only 38 per cent of the small secondary school population go to university. Secondary school enrolment in Malawi and Tanzania is less than 10 per cent.

Science education can do nothing to promote better access. However, to those in school, equity becomes a curriculum issue. Reddy reports a study by Obura (1991) showing that laboratory costs of teaching conventional science in secondary schools are US $20,000 in Nairobi, $32,000 in a rural area close to a tarred road and $40,000 off the tarred road. Not surprisingly, few rural schools offer science subjects, especially chemistry and physics which require specialised equipment. Of all candidates registered in Kenya for senior examinations in 1994, Reddy, quoting Wasanga (1995), claims that 22 per cent studied physics, 42 per cent chemistry and 58 per cent physical science. In Nigeria (Okebukola, 1995) claims that 93 per cent of senior secondary students studied biology, 30 per cent chemistry and 16 per cent physics. Clearly, a curriculum based on learning science through the local environment would be less costly, thus making the subject more accessible to all students. Furthermore, the content of traditional science often has a strong cultural bias that can deny intellectual access to groups such as villagers, pastoralists and girls. Textbook examples and illustrations are generally framed in urban, male settings. Classroom interactions favour boys, especially those with a good command of English. Again, these are professional issues that science educators can change by localising the curriculum.

In Africa, applied science is a tool for development. Its purpose is to improve the quality of life of the continent's people and to contribute to economic development. A characteristic of applied science is that it uses knowledge to solve problems in the immediate environment and community, whereas the characteristic of research science is to acquire new knowledge. Should school science curricula use community resources, doing so would be relevant to the bulk of school leavers and be a more appropriate preparation for the few who will engage in applied science as, for example, agriculturists, medical staff and industrialists.

Though preparing for research science should not be a goal of school science, for the most part in Africa today, the school knowledge base assumes that it is. Rollnick (1998) notes that Ogunniyi (1986) laments the isolation of African scientists from the debate on curriculum development. Most scientists complain that existing secondary science courses do not prepare students for research science in the university. Many think that a problem-solving approach based on learning from community resources is a better preparation for even future research scientists.

Whose science education?

Science education in countries of sub-Saharan Africa is accessible only to the few, particularly at post-primary levels of schooling. The Jomtiem Conference, making a call for education for all across the world, initiated a call for science education for all. Most African countries recognise the issues of increasing access to science education. The realities of doing so, however, include more human, physical and financial resources than most realise. Science for all can only become a reality at primary and lower secondary school levels if a single science subject is offered, rather than separate subjects such as agriculture, biology, chemistry and physics. Separate subjects do not make epistemological sense at these levels of schooling and are costly. Therefore science education that is rooted in the physical and human resource base of local communities better addresses the realities of Africa than education in the separate disciplines. It would be a more appropriate, accessible and cost-effective science education that African countries could deliver.

Social Impact of Science Education

Science and technology, and science and technology education, has not had the hoped for impacts, as Reddy, Fabiano and others repeatedly point out. 'Odhiambo, 1993, estimates that ... most African countries have fewer than three scientists and engineers per 1000 graduates and that the industrial sector employs only 7 per cent of the workforce' (Fabiano, 1998). We recognise this unfortunate legacy of a hierarchical, academic and centralised science education system in our recommendation that science teaching in our schools should be inquiry based, using the resources and knowledge base of local communities.

Countries of sub-Saharan Africa cannot afford specialised secondary schools. Most pre-vocational courses offered in primary and secondary schools are unpopular and ineffective (Yoloye, 1998). Yet the decentralised economies of Africa desperately need the problem-solving, 'tinkering' ethos that contributed so much during the period when Europe and the USA industrialised. Teaching inquiry science using the community resources and knowledge base would develop such a spirit amongst those living in the agricultural and informal sectors. It is such people upon whom the economic future of Africa depends. It is they who will have to make decisions about how best to use the technologies needed to transform the quality of life such as improved crops and farming methods, alternative energy sources and best preventive health practices. It is the rural and urban dwellers who will have to evolve their own solutions to such everyday problems and whose purchasing power will drive the economies of Africa.

Employers, including government and universities, constantly complain of the lack of initiative, team spirit and complacency of their employees, and it is within these sectors that 'low' and 'high' science are practised. Initiative, team spirit and determination are precisely the qualities promoted by inquiry science. Inquiry science has a deep impact on classroom relationships since inquiry is motivated by students' interest and authority lies with whoever can best marshal and interpret evidence. In such a learning environment, teacher-dominated and often male-centred patterns of interaction become less predominant. A facility with language, familiarity with the so-called culturally neutral rules of the classroom and masculine interests promoted by the conventional syllabus and textbook all become less important. Presenting science as a discipline that is activity engaged in by people to solve problems they identify, shifts it to Phase 5 of the model developed by McIntosh and discussed by Harris (Commonwealth Secretariat, 1999). Harris argues, and we agree, that only by restructuring the subject and the accompanying pedagogy can we truly promote an equitable access to science and technology regardless of class, culture or gender, though she does not deny the importance of other programmes that promote equity.

An equally important goal of teaching inquiry science using community resources is the development of qualities of good citizenship and governance. As Greick argues:

Memorisation replaced understanding ... Students learned names and abstract formulations ... Words about words ... Feynman despised this kind of knowledge ... Rote learning drained away all that he valued in science: the inventive soul, the habit of seeking better ways to do anything. His kind of knowledge – knowledge by doing – gives a feeling of stability and reality about the world and drives out many fears and superstitions ... Science is a way to teach how something gets to be known, what is *not known, to what extent things are known (for nothing is known absolutely), how to handle doubt and uncertainty, what the rules of evidence are, how to think about things so that judgments can be made, how to distinguish truth from fraud, and from show.*

Genius: The Life and Science of Richard Feynman, pp. 284–5

We believe that inquiry science will bring to the children and youth an Africa blessed with an environment rich in the phenomena of nature. This should be a science that '... permits the possibility that you do not have it exactly right...' and that educates young minds 'to deal with doubt and uncertainty', an experience the value of which Feynman believed '... extends beyond the sciences' (*New York Times*, 17 May 1998). Feynman believed in the deep connections that link science with democracy – Africa surely needs sceptical, reflective citizens. Africa also needs tinkering problem solvers at all levels who are prepared to suspend judgment when there is insufficient evidence. Liberal, rather than social, democracy, as Dahl (1998) argues, requires that all members of the community are equally entitled to, and are competent in, collective decision-making; that they have an 'enlightened understanding' of political issues. We believe that inquiry, rather than traditional science, best develops such qualities.

Delivery of Science Education

Subsequent chapters describe projects that use both formal and informal structures to implement the teaching of inquiry science. They demonstrate that with good planning and minimal support, the countries of sub-Saharan Africa can develop structures that promote quality science education. Chapter 12, 'Malawi and Zanzibar: Exemplars of Inquiry Science in School and Community', provides a rich description of how outstanding classroom teachers popularise the science and technology education we have advocated in this chapter. It identifies the impact of their work on the community, and analyses what inspires and sustains their work. Chapter 10 discusses how teacher development programmes can systematically provide such inspiration and support to enable teachers to popularise inquiry. Chapter 11, 'Using the Mass Media to Promote Science and Technology', shows how informal mechanisms can effectively popularise science and technology and Chapter 4, 'University Science and Technology Education and Economic Development', illustrates how research science can link with 'traditional science' to solve development problems. Chapter 16 briefly describes a government (that of South Africa) that effectively co-ordinates national popularisation programmes.

Those in positions to influence events should know what is possible. Ignorance of what has been achieved by some science educators in Africa should not be a reason to block change. And we know that African children and teachers are not the problem blocking the achievement of a vision of inquiry-based science and technology education.