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# Science and Technology Research for Sustainable Development in Africa: The Imperative of Education (Pp. 71-89)

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**Abstract**
*The dichotomy of the world along two economic poles, of developed and developing is mostly linked to the level of science and technology sophistication. This implies that science and technology play pivotal roles in the development of nations. However, to be effective and relevant, science and technology must be carried out in such a way that promotes sustainable development. This is because there are certain issues that are associated with science and technology that need to be properly addressed. Some of these issues are social, economic, ethical, political and environmental. The totality*

*of all these can be said to be what constitutes sustainable development. The global power play is focused on the levels of science and technology of nations. This has placed African countries at a disadvantage. There are also ethical implications of these vital aspects of man's endavour. Science and technology are human centered since they strive to make man to conquer, domesticate his environment and understand nature towards making man comfortable. This makes science and technology to provoke certain epistemological questions that border on the relevance and benefits of science and technology. In this paper, effort is made to establish the imperative of education to science and technology.*

**Introduction**

The widening economic gaps that exit between nations are attributed to corresponding gaps in science and technology. To be effective, science and technology have to maintain relevance and have sufficient resource base. To maintain relevance and attract support from influential sectors, science and technology research and development criteria must be set locally. By maintaining relevance and gaining support, research and development, should contribute effectively to economic development and influence emerging national policies and practices.

A fundamental need for development of science, technology, research and national development is to establish a sound educational system. This educational system must be anchored on a sound philosophical foundation that encourages partnership for exchange of people, ideas, and support facilities. The universities and research institutes in different African countries should enhance their relevance to society through the development of partnerships with the local community, industry and national research facilities. Educational institutions should be open to meet the needs of the local industries, people and environment, while updating their research programmes and activities to meet and satisfy the practical needs of the society. Local research and development should be as selective as possible so as to avoid mismanagement of scarce resources. However, these linkages should not be made to be limited nationally, but should extend to include regional and international elements. These actions will go a long way to enhance educational expertise both for instructions and for the students. Research and development should be coupled with the educational goals of African countries and their universities to promote and strengthen national economies. The emergence of stronger economies will in several ways

contribute through educational exchange programmes, partnerships and linkages to an equally stronger regional economy.

To promote sustainable science and technology research and development in Africa the most important and strategic thing to do is to employ education and educational institutions as vital tools towards this goal. This is anchored on the logic that, the sustained prosperity of a nation depends upon the level and quality of its education system. Education as it has been argued empowers individuals and maximizes national intellectual resources in order to sustain social and economic progress for the benefit of all. It is on the basis of this that the paper advocates for the effective utilization of education and educational institutions for the attainment of sustainable development through science and technology research. This approach will broaden the scope of science and technology research as it will bring about scientific and technological literacy among the citizenry. This however, should be based on a philosophy of education that will promote science and technology.

**Science and Education**

Science is generally seen as the means through which knowledge is arranged in an organized pattern. Also, this knowledge is derivable from experience, observation and experimentation (Ekanem, 2007). This notion of science tallies with the *Oxford Advanced Dictionary of Current English* as it defines science as, "…The study of the structure and behaviour of the physical and natural world and society, especially through observation and experience" (2002).

From this, it can be argued that science is concerned about the observation of the environment, which proper understanding is made possible through experiential process. Therefore, science is the sensory process of epistemological comprehension of nature towards the discovery of objective principles that aid man to logically interpret and domesticate the environment without dislocating the web of nature. It is the process of penetrating nature with the aim of discovering the laws that aid man to live sustainably. This is the relationship between man and his environment, which is based on careful and objective study by man to sustain the relationship (Ekanem, 2007).

If science is considered as the relationship between man and his environment that requires a careful and objective study by man to sustain the relationship, then education becomes very crucial and relevant here. This is so because education, as a social factor is relationship dependent for it to strive. It is a means through which an individual acquires adequate knowledge of social

values that enable the individual to function effectively as a member of a given society. So, knowledge of social values that aids the individual to function effectively as a member of a given society include that of nature, environment, the discovery of objective principles and laws that aid man to logically interpret and domesticate his environment without posing any danger (sustainability ).

This indicates an intrinsic relationship between science and education. This becomes more fundamental when it is discovered that both science and education are human epistemological activities that help to advance the course of man and society. Both activities are human means of bringing about change through the process of discovering, understanding and logical interpretation. This discovery mostly within the realm of science could be either negative or positive. This then requires a rationale to prevent or eliminate the negative consequences of science, or and sustain the positive effects of sciences (discovery). This rationale can only be attained through the process of education. This provides justification for the relationship notion of education as earlier stated.

This process of education about science and its activities can bring about the social value or benefit of scientific literacy. Scientific literacy here include reference to science for citizenship and concern for the knowledge of science with specific attention to the process of science (Dangs, 1970, Agin, 1974, Umoren, 1996); this also involves science culture (Ajeyaleni, 1983); scientific enlightenment (Hurd,1970; science related attitude (Akindelun, 19850;) the habit of scientific thinking (Noll, 1933); and the spirit of science (Educational Policies Commission, 1966).

Indeed, scientific literacy implies the fact that scientifically literate person is one who:

> Knows something of the role of Science in society and appreciates the cultural condition under which science survives and knows the conceptual inventions and investigative procedure. A scientifically literate person understands the interrelationship of science and society, ethics which controls a scientist, the nature of science which includes basic concepts and the interrelationship of science and humanities (NSTA, 1964).

This scientifically literate person can only emerge through the process of education. And as Umoren (1996) quotes the NSTA, the scientifically literate person is equipped to:

1. Use science concepts, process, skills, and values in making everyday decisions as he interacts with other people and with his environment.
2. Understand that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories.
3. Distinguish between scientific evidence and personal opinion.
4. Identify the relationship between facts and theory.
5. Recognize the limitation as well as the usefulness of science and technology in advancing human welfare.
6. Understand the interrelationship between science, technology, and other facets of society, including social and economic development.
7. Recognize the human origin of science and understand that scientific knowledge is tentative, subject to change as evidence accumulates.
8. Have sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others.
9. Have a richer and more exciting view of the world as a result of his science education.
10. Have adopted values similar to those that he can use and enjoy science for its intellectual stimulation, its excitement of inquiry
11. Continue to acquire and increase his scientific knowledge throughout life.

These clearly identify the benefits of education when it is applied to science or scientific research. There cannot be scientific research without education and educational institutions. Education helps to liberate man from the stronghold of belief, superstition and tradition. Education attempts and makes the human mind(s) scientific. It also helps to stimulate thinking and curiosity, which is the starting point of any scientific inquiry. It is through education that ideas are gathered, formed and developed.

It could therefore be gleaned from this that education is the foundation of modern science. Without education, there could be no science as we know it today. And without science, the understanding of the universe, nature and the environment would not have been made possible. It follows that; there would have been no development without education. So, education plays catalytic role in scientific development. But the issue is, how can this development be carried out sustainably?

**Technology and Education**

Technology is generally viewed as the application of scientific knowledge to arts or in doing things. This scientific knowledge can be either theory or practice. However, the practical application of scientific knowledge seems more imposing in the entire enterprise or edifice. And the goal or essence of this is the creation of a more comfortable life and sustenance of human existence (Ekanem, 2007). From this perspective, some authors like Marden (1970) views technology as a practical application of systematized knowledge, which is for the benefit of man and the comfort of his life.

From this, it is understood that technology involves a body of systematic application of practical knowledge with the ultimate goal of enhancing human existence, and this is not one- directional but rather multi-dimensional. The reason for this is because there are several aspects or facets of human existence that require improvement before we can actually get to the point that can be referred to as "human comfort". Man unarguably is a complex being with many aspects and this include his existence. It is on the basis of this that we have various aspects of technology, which include medical, military, marine, building, science, industrial and information technologies.

With these various aspects of technologies without education, a great disaster would have befallen mankind. Education helps to ensure that the application of scientific knowledge is properly directed. With the systematic utilization of materials, machines, tools scientific, mathematical and general knowledge, energy sources, natural phenomomena to design and coustruct goods and services in order to solve practical problems as they arise. Indeed education helps to bring about technological literacy (Ekanem, 2007).

This can be seen in the words of Umoren (1996), when she defines technological literacy as " the acquisition of a wide knowledge of technology both from school and environment with the necessary attitudes (ethics), skills (processes) and relevant physical abilities necessary to apply the knowledge

and skills gained in a safe, appropriate, efficient and effective manner.' She further argues that "it is technological literacy that grooms individuals to be able to perform tasks using tools, machines, materials and processes of technology, and to be able to function effectively in the world…."

It is clear from this that education and educational institutions make technological literacy possible, and this is defined by certain characteristics. To Dyrenfurth (1987), technological literacy is categorized into three domains namely, the cognitive, the affective and the psychomotor.

Based on this therefore, within the cognitive domain, the charactiseristic of the technologically literate person are:

1. Awareness of key processes and their governing principles (what` is it and how does it works).
2. Understanding of essential relationship among key areas of technology.
3. Ability to conceptualize how unfamiliar technological process or machine operates
4. A sense of personal limits (when to call in an expert).
5. Familiarity with technological process or product in terms of personal benefit as a consumer.
6. Ability to evaluate a technological process or product in terms of personal benefit as a customer.
7. Insight as to the relationship between careers and the technological future.
8. Ability to project alternative future based on technological capacities and application
9. Knowledge of technological information accessing methods and sources.

Within the affective domain, the characteristics portrayed include:

i Comfort with basic technological hardware (willingness to use tools, machines and materials.)

ii Imagination to apply existing technology to new problems or situations

iii Ability to evaluate a technological process or product in terms of personal benefits as a consumer.

iv Ability to choose among technological alternatives in daily life.

In the sphere of the psychomotor, the characteristics are:

(i) Ability to use technological artifacts (tools, machines, materials and processes) commensurate with one's stage of development.

(ii) Ability to use technological artifacts (tools, machines, materials and processes) commensurate with one's life.

Basically, the knowledge or technology achievable through education can only bring about sustainable development where all these characteristics are present. So, for any society to be developed sustain ably, the educational system should produce high level of technological literacy. The significance of this is graphically captured by Dyrenfurrth (1987).

> Technology is the essence of the economy of what we call "developed" countries. Absence of Technology leads to our euphemism of developing countries. Not only does technology play a pivotal role in our economic world, it also determines the extent to which we can defend ourselves and in large part, the level of our quality of life. It is a significant focus of the recreational activity of millions and the cornerstone of a healthy future. Because of its acknowledged importance, technology carries with it considerable responsibility and even threat. Misuse of technology is well known to even lay persons and more than a few knowledgeable experts have forecasted doom precipitated by mankind's use/abuse of technology. Therefore, it would seem that the hope for a future in which people are in control of their environment lies in universal technological literacy or the ability to do and to use technology. Not just be aware of it. Technology feeds on imagination, impudence, science and most especially on technology itself. In order to accomplish human resource development, a large proportion, if not all of our societies

> need to be relatively competent with technology. Technological literacy is the foundation of such competence.

Indeed, technological literary is the basis for flexibility in the future. It helps people to control and assess technology. It also helps people to adapt to the dynamism of the society and be able to contribute to the advancement of its capabilities. This enhances entrepreneurial capacity, helps the individuals *in* making a well informed and rational occupational choice, thereby bring about better citizenship (Umoren, 1996).

It is on the basis of this that the educational system and institutions that drive scientific and technological development need be founded on a philosophy of education. This is because scientific advances and technological innovations have greatly contributed to social progress and cultural problems in Africa generally. There appears to be a general awareness of the contributions of science and technology to social transformation and changes. However, in the sphere of science and technology most African countries especially Nigeria according to Umoren is a mere starter. She anchored her argument on the high illiteracy rate, coupled with an ever unstable political system/economy, an unenlightened political leadership, a conspicuously heterogeneous society, and lack of sustained cumulative intellectual tradition. Evidence are available to prove that the type of science taught in the primary and secondary schools and up to universities is devoid of practical application but rather are ready made knowledge which is far removed from the African cultural background.

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?

If the answer to this is that, they think or reason in English and in French, then their intellectual scope and nourishment will not be able to satisfy the socio-cultural needs of the Africans.

From this, it is established that knowledge is the most powerful engine room of scientific and technological development. This is because the socio-economic needs, which are the source of comfort that technology provides humanity, need be knowledge driven. This knowledge, it is believed can best be provided through an educational system. And for the system to be effective, it must be based on a philosophy that will inspire scientific creativity, technological innovation and practical application of knowledge.

Today, there are a number of processes at work, some entirely new, and others that have been developed or designed over the years, which together are transforming the methods of doing things and the modes of organizational operations. This in a very vital way demands that there should be a renewed focus on knowledge as a means of improving the society through the use of science and technology that enhance performance. The increasing importance of knowledge driven society or economy of knowledge driven society or economy is indeed an international trend, which have tremendous effects on all levels of development. So, for any country that wishes to be in the vanguard of the world or regional economy, the balance between knowledge and resources must necessarily be shifted towards the former since knowledge has become the most important factor in the determination of the standard of living. This is most fundamental and imperative when it is realized that today's most scientifically and technologically advanced economies are basically and truly knowledge- based. The emergence of knowledge- based economies has profound implications for the determinants of growth and development.

By knowledge driven economy, we mean the generation and exploitation of knowledge for the all important motive of creating wealth that will assist in the sustenance of humanity. It is not just about pushing back the frontier of knowledge, it is all about the more effective use and exploitation of all types of knowledge in all sphere of economic activity in which science and technology play pivotal roles. From here, the question to be asked is; what is knowledge or what do we mean by knowledge? Knowledge as applied here transcends mere information about one's environment. Though there is a great amount of information that is produced and provided, but this does not mean that we are all knowledgeable because of the information that is at our disposal. It is one thing to have information but it is another thing altogether to interpret and apply information in the best practical way based on experience, expertise and needs. So, to understand the function of knowledge at the macro level of our economy as it relates to science and technology, it is

imperative that we distinguish between two basic forms of knowledge which are:

i. Codified – codifiable knowledge is that which is documented and could be easily transferred to others and;

ii. Tacit – which is usually very slow in its acquisition. This could be knowledge acquired during an apprenticeship, understanding how certain thing work and being familiar with a particular technology.

The difference in the transferability of these two kinds of knowledge implies that both should be effectively managed, utilized, combined and rewarded differently. And because of its nature, tacit knowledge usually has competitive edge. The importance of knowledge element in science and technology is very obvious around us. Indeed, knowledge tends to be transforming and improving every facet of human's existence. The value and importance of knowledge can be seen in four distinct mutually reinforcing processes, which are:

i. Information and Communication Technology (ICT)

ii. Increasing speed of Scientific and Technological advance, which is largely due to the basic scientific research.

iii. Global competition

iv. Changing demand is clearly linked with increase in income and the changing pattern in terms of tastes and attitudes to leisure, which is made possible by prosperity that is created through scientific and technological innovations.

In today's world, science and technology have been integrated into human culture. As fundamentals social process, science and technology have become very vital in our society. Therefore, the social justification for their development has been both intellectual and material. Through science, man is supposed to have a better understand of nature, environment and society. They are also supposed to liberate man from the chain of superstition and ignorance. Technology, which is derivable from science, was to "provide us with absolute control over the material world. From this man was to achieve total liberation "from hard work, hunger and poverty" (Umoren 1996). Despite the promises of science and technology, Africa remains as a mere spectator in this vital sphere of human endeavor. This is basically due to the

high illiteracy rate (lack of proper education) in African countries such as Nigeria, Niger, Burkina Faso, Kenya, Ethiopia, and Cameroon among others. There are the problems that have to do with conceptual and cultural practices that have hampered and frustrated efforts made at bringing about scientific and technological development in African countries. There is the lack of quality number of technical, scientific, professional and managerial personnel to implement such programmes. As a result, most African countries like Nigeria according to Umoren (1996) is at risk, for the mere fact that the educational foundation of our society is seriously being eroded by rising tide of mediocrity, which posed a fundamental threat to the future of the continent. She argues that because Africa is producing scientifically and technologically illiterate populace, hence Africa cannot achieve technological progress. This could lead to what Umoren (1991) described as ignorance or fear of science and technology. To suffer from this in the 21st century will lead to the production of techno peasant citizens who are according to Prewitt as quoted by Umoren (1997) are those who are bewildered and intimidated by the new techniques and languages of science and technology. The implication of this is that Africans are and will be outsiders in their various countries. Accordingly, any nation,

> ... without a scientifically educated citizenry cannot be expected to make any reasonable technical based political decision on such issues as nuclear energy and atmospheric pollution because of the lack of the rudimentary tool to grasp the various arguments. Thus to teach the young people science is to educate the society's future scientists and thus lay the foundation for scientifically enlightened polity informed on scientific matters that affect the citizens' lives from day to day (Umoren, 1997).

From this, it is discovered that education becomes a conditio- sine-qua-non for the development of science and technology. This therefore calls for massive education of the people. And since the 21st century require people that "have the savvy to explore, understand and to some degree control their own fate in the society", which is clearly redesigned by science and technological development, there is the need for this education to have a philophical base that will define the focus of the new scientific and technological society. This education will promote and advocate scientific literacy and the practical application of scientific knowledge to bring about societal development. For the American Association for the Advancement of

Science (AAS), this form of literacy is seen as the ability to apply scientific knowledge and methods of reading for private and public purposes. The argument is that our choices in the application of science knowledge are intricately tied up to risks and benefits, social trade- offs, value judgement and compromise. Scientific literacy involves the abilities to apply scientific knowledge to our everyday life or living.

Therefore, technological literacy is an adjunct to scientific literacy as this involves a better comprehension of current technologies, its capacities, scope and limitations, the basic concepts, theories, and social impact. This understanding of science and technology can better be grasped through philosophy of education which will sanitize, evaluate and analyses scientific concepts, theories, laws and generalizations. It will also raise a standard ethics and logic of scientific and technological development. With its critical nature, philosophy of education will help to engineer a kind of scientific and technological development that will be socially and culturally relevant and responsible. It will also inspire critical thinking in the scientists and technologists that will go a long way to reshape their focus. At the end, the products or scientific and technological development will be within the ambitious angle of providing comfort to man and not to destroy nor dehumanize.

With a sound philosophy of education, scientific and technological researches and pursuits will be refocused towards the enhancement of the conditions of life. It will help to check the destructive tendencies of some sciences and technologies.

Philosophy of education directed at bringing about a new scientific culture in African countries will go a long way to preserve the continent's natural environment. This is because the new scientists and technologists will be educated to obey the natural laws and maintain its principles. Life in the new techno-culture will be sacred and not subject of experimentation based on trial and error techniques. The new approach to scientific and technological advancement will be more systematic, human and environmental friendly. This way, there will be a drastic reduction in the dislocation of natural web of things.

**Recommendations**

To achieve sustainable science and technology research and development in Africa certain strategic steps must be taken or adopted by African countries

It is important that partnership and linkages be established between various sectors within each country, and African countries. These interactions should involve exchange programmes, cooperation between industries and educational institutions, linkages in research facilities, and identifications of other mechanisms and sources of assistance and support. These interactions should be promoted at all levels of national, regional and international.

Also, there must be a commitment towards increasing the level of literacy and numeracy by all nations. Indeed, this should be a prime requirement. Towards this end, African countries must establish, through their national education policies, strong links between stakeholders in their educational system to ensure curriculum development that is science and technology based across the full educational process.

Also, African countries should seek more sponsorship or assistance from international donor agencies and from the private sector, recognizing the fact that African's local resources are inadequate. There should be a determined effort by African countries to close the gap between African's educational system and that of the developed world.

Again, African countries must raise the level of awareness of the value of science and technology research among the general population and among those that influence educational policies.

Scientists and technologists from educational institutions and industries should be included in designing the curriculum. The curriculum should basically be designed to meet the needs of Africa and address the immediate needs that include awareness of the environment. Topics such as pollution, hydro climate variability, conservation, use of natural resources and soil erosion should be included. The curriculum for early study years should emphasis mathematics and science which is to ensure that all students are given the opportunity to study science later.

Furthermore, there is the need to raise the level of academic quality of teaching, especially in the pre-university educational sector. To this end a closer linking of pre-service training education of teachers with universities is encouraged. Science and mathematics must be included in all training Programmes of teachers development workshops as a kind of in-service training for science teachers should be made compulsory.

Again, there should be an international support for educational programmes in Africa. This should be in recognition of the large gap between the

educational systems in Africa as a whole and those of the industrialized world, and noting the lack of local resources, and so the international sponsorship of programmes should involve the following

i. Widening of access for women education up to higher education.

ii. To identify appropriate methods for nurturing and assisting African education programmes through the most successful international programmes.

iii. Massive continuing and adult education programme to develop an improved knowledge base and general awareness of the benefits of science and technology.

iv. Development of support and teaching materials to help the learning process for students who mother tongue is not that used for science and technology study.

v. Constant review of academic contents and levels of achievement within science and technology programmes in the whole of Africa.

vi. Funding of academic staff exchange programmes at all levels of the educational system coupled with back-up funding to ensure implementation of the educational experience in Africa.

vii. Raise the Level of awareness of the value of science and technology among the general population and those that can influence educational policies

viii. Stimulation of early awareness of science and technology among young people and consideration given to the development of low-cost early childhood learning materials based on science and technology that are relevant to Africa. This project would assist the development of skills among the young people of Africa.

ix. Formulation of policy that will increase the gross domestic product (GDP) percentage invested in science and technology beginning with a target of two percent (2%) and gradually increasing to five percent (5%) within fifteen years.

x. Development of a political consensus on the need for a strong science and technology policy.

xi. Ensure adequate funding of education and prevent brain drain in Africa Governments should explore strategies that will ensure effective private sector contributions to any investment in education generally.

**Summary and Conclusion**

It is recognized that science and technology development is a necessary condition for the peaceful social development of the African continent, the necessity of which is very obvious, and the sustainability of which requires adequate human and financial resources to be made available to the science and technology sector.

It is also discovered that there is a close relationship between education, science and technology research. This demand on education, which is taken as a conditio-sine-qua-non for sustainable development of science and technology, it was argued, must be founded on a philosophy of education that will help to reshape and refocus scientific and technological development. This will make development in the area of science and technology to be human and environmental friendly. This is anchored on the importance of knowledge in the development of the society and the economy, which science and technology play pivotal roles.

Finally, African strategic programme to enhance education in science and technology should recognize the various stakeholders, their interrelationships, and the changing roles in the process and effort to provide quality education. Every African country, nationally and with its neighbours, should build strong linkages among the various stakeholders. A systematic approach should be developed to assess and evaluate the needs, the problems and the possible solutions for, each entire educational system.

African leaders must show strong political will in terms of practical approach to stem the tide of brain drain by funding education maximally and being prudent, in managers of scare resources, recognizing the limits of local resources and the need to share some of them. There is also the need to explore national and international resources towards achieving the educational objectives. It is also very vital and necessary to increase the level of awareness about the value and contributions of science and technology, especially among policy makers as its relates to science, technology and education.

Indeed, with a sound philosophy of education, a stable educational system, that is better funded and well enlightened citizenry about the value and contribution of science and technology, with the aim to improve human existence on planet earth, Africa can be a leading continent in the world in terms of sustainable development. This is because of the vast human material resources available in the continent.

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