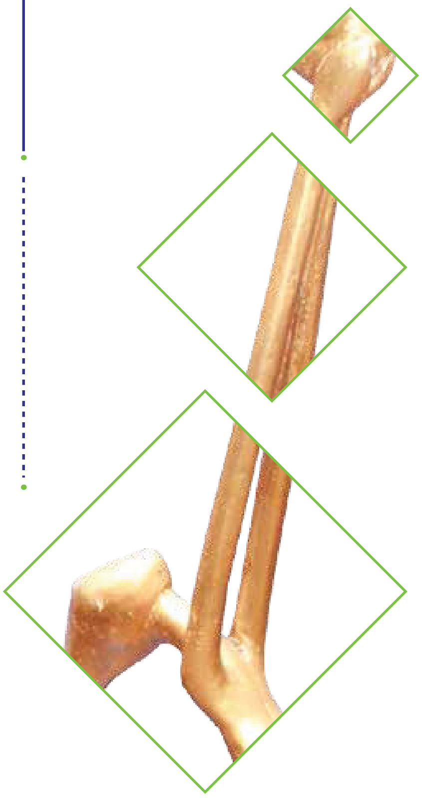
Triennale
Education and Training in Africa

Lifelong Acquisition of Scientific and Technological Knowledge and Skills for the Sustainable Development of Africa in the Context of Globalization



Synthesis prepared on the occasion of the 2012 ADEA Triennale on Education and Training in Africa on the theme:

Promoting Critical Knowledge, Skills and Qualifications for Sustainable Development in Africa

ADEA 25 1988–2013
Ans au service de l'éducation en Afrique
Years serving education in Africa

ADEA
Ushirika wa Maendeleo ya Elimu Barani Afrika
الرابطة لأجل تطوير التربية في إفريقيا
Association for the Development of Education in Africa
Association pour le développement de l'éducation en Afrique
Associação para o Desenvolvimento da Educação em África

Ushirika wa Maendeleo ya Elimu Barani Afrika
الرابطة لأجل تطوير التربية في إفريقيا
Association for the Development of Education in Africa
Association pour le développement de l'éducation en Afrique
Associação para o Desenvolvimento da Educação em África

Lifelong acquisition of scientific and technological knowledge and skills for the sustainable development of Africa in the context of globalization

by Kabiru Kinyanjui and Khadija Khoudari

ADEA Triennale on Education and Training in Africa
Ouagadougou, Burkina Faso
February 12-17, 2012

Financial support for this publication is provided out of ADEA core funds, to which the following organizations are contributing members: Ministry of Education, Angola; Ministry of Education, Science and Technology, Kenya; Ministry of Primary and Secondary Education and Vocational Training (DRC); African Development Bank (AfDB); European Commission; United Nations Educational, Scientific and Cultural Organization (UNESCO); United Nations International Children's Fund (UNICEF); the World Bank; Federal Ministry for Foreign Affairs, Department of Development Cooperation, Austria; Canadian International Development Agency (CIDA); Ministry for Foreign Affairs, Finland; Ministry of Foreign Affairs, Department of International Cooperation and Development, France; German Cooperation (GIZ/BMZ); Irish Aid, Department of Foreign Affairs, Ireland; Japan International Cooperation Agency (JICA); Ministry of Foreign Affairs, Netherlands; Norwegian Agency for Development Cooperation (Norad); Calouste Gulbenkian Foundation, Portugal; Swiss Agency for Development and Cooperation (SDC), Switzerland; Department for International Development (DFID), United Kingdom; United States Agency for International Development (USAID).

Published by the Association for the Development of Education in Africa (ADEA). ISBN 10: 92-9178-134-7, ISBN 13: 978-92-9178-134-8

First print: December 2013.

A French edition of this book entitled « Acquisition tout au long de la vie de compétences scientifiques et technologiques, pour le développement durable de l'Afrique dans le contexte de la mondialisation » is available: ISBN 10: 92-9178-135-5, ISBN 13: 978-92-9178-135-5

Association for the Development of Education in Africa (ADEA)
African Development Bank (AfDB) – Temporary Relocation Agency
13 avenue du Ghana – BP 323 – 1002 Tunis Belvédère – Tunisia
tel: +216/ 71 10 39 86 – fax: +216/ 71 25 26 69
e-mail: adea@afdb.org – web site: www.adeanet.org

CONTENTS

List of figures, tables, and boxes

ACRONYMS AND ABBREVIATIONS

AAS	African Academy of Sciences
AAU	Association of African Universities
ABI	African Biosciences Initiative
ACTS	African Centre for Technology Studies
ADEA	Association for the Development of Education in Africa
AERC	African Economic Research Consortium
AfDB	African Development Bank
AIMS	Africa Institute of Mathematical Science
AISTI	African Institute of Science and Technology
ALC	African Laser Centre
ANSTI	African Network of Scientific and Technological Institutions
APHRC	Africa Population and Health Research Centre
ATPS	African Technology Policy Studies Network
ASSAF	Academy of Science of South Africa
ASTII	African Science, Technology and Innovation Indicators Initiative
ASTIPI	African Science, Technology and Innovation Policy Initiative
AU	African Union
AUCC	Association of Universities and Colleges of Canada
AUST	African University of Science and Technology
CARTA	Consortium for Advanced Research Training in Africa
CGIAR	Consultative Group of International Agricultural Research
COE	Center of excellence
COMESA	Common Market for Eastern and Southern African States
CPA	Consolidated Science and Technology Plan of Action
DAAD	German Academic Exchange Service
DFID	Department for International Development
EAC	East African Community
ECOWAS	Economic Community of West African States
EFA	Education for All
FOSS	Free and open-source software
GDP	Gross domestic product
HEI	Higher education institution
ICEGB	International Centre of Genetic Engineering and Biotechnology
ICIPE	International Centre for Insect Physiology and Ecology
ICT	Information and communication technology

ICRAF	World Agroforestry Centre
IDRC	International Development Research Centre
IK	Indigenous knowledge
ILO	International Labour Organization
ILRI	International Livestock Research Institute
ITU	International Telecommunication Union
IUCEA	International University Council for East Africa
JICA	Japan International Cooperation Agency
MDG	Millennium Development Goal
MIS	Management information system
LPA	Lagos Plan of Action
NEPAD	New Partnership for Africa's Development
OAU	Organization of African Union
OECD	Organization for Economic Co-operation and Development
PPP	Public-private partnership
PUIB	Public Universities Inspection Board
QA	Quality assurance
R&D	Research and development
REC	Regional economic community
S&T	Science and technology
SADC	Southern African Development Community
SIDA	Swedish International Cooperation Development Agency
SMEs	Small and medium enterprises
SSA	Sub-Saharan Africa
STEM	Science, technology, and mathematics
STI	Science, technology, and innovation
TT	Transfer of technology
TTCO	Transfer of technology central office
TVSD	Technical Vocational Skills Development
TVET	Technical and vocational education and training
USAID	United States Agency for International Development
USHEPiA	University, Science, Humanities and Engineering Partnership in Africa
UIS	UNESCO Institute of Statistics
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Population Fund
WB	World Bank
WGHE	Working Group on Higher Education
WIPO	World Intellectual Property Organization

INTRODUCTION

This paper attempted to identify ways and means of building and strengthening Africa's capacity to acquire, generate, adopt, and utilize scientific and technological knowledge and skills to confront the myriad and diverse challenges of sustainable and equitable development in Africa in the context of rapid globalization. The underlying assumption of the paper is that Africa's development must be fully anchored on the acquisition and utilization of high level knowledge and skills by and for its people. This is essential if the continent must effectively exploit its abundant natural resources to alleviate poverty, create employment for youth, avoid endemic conflicts, and achieve sustainable socio-economic development. This must be realized in the context of democratic transformation, accountability, inclusion, and gainful engagement at the global level.

To realize the above, Africa needs to undertake a number of well-calculated measures and systematic strategies. These include: articulating a vision of scientific and technological development; investing in lifelong quality learning of skills for communication, mathematics and science; cultivating an education system that incorporates indigenous knowledge; investing creatively in the scientific and technological capacity of all its youth; revitalizing tertiary education and linking its innovations to productive sectors; working towards the inclusion of women and marginalized groups in processes and institutions of science and technology; and building strong infrastructure for knowledge creation and innovation while strengthening regional and international cooperation in science, technology, and innovation.

This synthesis papers brings out salient points that require the attention of policy makers, educators, scientists, economic actors, development partners, and civil society players keen to build and intensify utilization of scientific and technological capacities in the transformation of African societies and overall sustainable development.

Guiding concepts

The synthesis is guided by three interrelated concepts. First, the concept of lifelong learning that entails continuous acquisition and renewal of scientific and technological knowledge and skills from childhood to adulthood, through education, training, working, and life situations. It underscores and recognizes obsolescence of knowledge and skills and the need to retool and acquire new knowledge and know-how. Thus, learning to learn, critical thinking, openness to new ideas and ways of doing things, and ingenuity are the key attributes. Second, the concept of sustainable development that implies careful utilization of current resources to meet present needs while being stewards for the future generations. Third, global integration and competitiveness, meaning that Africa has to take up its rightful place in the world, not only as a producer of raw materials and consumer of imported products, but as a critical manufacturer and producer of goods and services that add value to its natural resources and create products and innovations that compete in the global knowledge economy.

Methodology

This document articulates in a summary form the collective desires and aspirations of the African people vis-à-vis the role of science and technology as discerned in the past three decades in various fora: heads of government summits, policy workshops, scholarly discourses and research documents. These include the views of political leaders, policy makers, development partners, private sector players, civil society actors, scholars and researchers. The synthesis is informed by studies and other contributions from country teams, development agencies, the private sector, the ADEA Working Group on Higher Education (WGHE), regional organizations, and individual consultants. Studies by regional research networks and researchers were also utilized. The contributions were supplemented by a literature review of documents and reports of the African Union (AU) and New Partnership for Africa's Development (NEPAD), the World Bank, UNESCO, the United Nations Economic Commission for Africa (UNECA), and the African Development Bank (AfDB). The document also benefitted from discussions and inputs provided by participants at the 2012 ADEA Triennale in Ouagadougou, Burkina Faso, and the subsequent science, technology and innovation (STI) conference held in Nairobi, Kenya, in April 2012.

As such, it incorporates broad lessons and experiences from all regions in Africa.

Scientific and technological development: Global and African contexts

In the past three decades, the world has experienced the unprecedented development of scientific and technological knowledge and know-how, which in turn has led to the creation of new technologies, processes, and products. Innovation has been the hallmark of this epoch. The economies of developed and emerging countries have been fundamentally transformed, as they shifted into knowledge societies.

Developed countries in the West as well as Japan and the emerging economies of Asia and Latin America have embraced the ongoing global transformation through science and technology. Consequently, they are investing enormous resources to strengthen their research capacity, institutions, and programs not only to spur socio-economic development but also to enhance competitiveness and expand their share of the global market. Universities and research institutions are therefore not only in the forefront of increasing human capacities for their expanding economies, but are also undertaking cutting-edge research and development (R&D). Emerging economies, in particular, have accelerated their investments in R&D as shown by the proportion of their gross domestic product (GDP) being devoted to the generation of new knowledge and innovations: South Korea - 3.5%; Singapore - 2.6%; China - 1.5%; Brazil -1%; Malaysia - 0.8% and India - 0.6% (UIS, 2009). As a result, the economies of these countries have become highly competitive in the development and output of scientific and technological research and innovations. Their readiness to bring new products into the market has generated fierce global competition as evidenced recently between Apple (USA) and Samsung (South Korea) corporations. The world has therefore become a highly competitive marketplace for ideas, creativity, and innovations.

While Africa is richly endowed with natural resources, it is nevertheless economically marginalized in the global knowledge economy because of its low scientific and technological capacity. Africa's share of global trade is also marginal, being about 3% (AfDB, 2009). The continent has 15% of the global population, but its scientific and technological publications compare poorly with other regions, standing at less than 2% (Pouris and Pouris, 2009; ATPS, 2010; Hassan, 2009). The leading African countries in this respect are Egypt, Morocco, Nigeria, South Africa, and Tunisia. On average, African countries allocate 0.3% of their GDP to R& D.

Thus, most African countries continue to be predominantly producers of raw materials: oil, minerals, and agricultural commodities. It is highly regrettable that since independence no significant move has been made towards value-addition to primary products. This is a persistent challenge to the continent's scientific and technological capability and industrialization. Africa's scientific and technological advancement is also caught up in the challenges of building and entrenching democratic institutions and practices, ending civil conflicts and wars, realizing the Millennium Development Goals (MDGs), and ensuring sustainable and effective management of natural resources in the context of climate change. Another major challenge is turning the relatively youthful population into a demographic dividend. Additionally, there is a persistent need for deepening regional integration by accelerating inter-Africa trade, enhancing national and regional infrastructure, and effectively utilizing the available resources and expertise.

All these challenges points towards the necessity of building credible African scientific and technological capacity and capability geared towards utilizing the enormous natural resources and youthful population to create employment opportunities and wealth for the present and future generations. In this context, Africa needs to identify critical drivers in the transformation of the current situation into the envisaged rapid and sustainable socio-economic growth (AU/NEPAD, 2007).

The paper has indentified key drivers and actions to be taken by various stakeholders to enable Africa to not only run, but to do so faster than other regions, in order to catch-up and win the global marathon against poverty while ensuring sustainable development. ■

01

ARTICULATION OF SCIENCE AND TECHNOLOGY POLICIES AND PROGRAMS IN AFRICA

1.1 BACKGROUND AND CONTINENTAL INITIATIVES

Since the 1970s, African countries have articulated policies and programs geared towards harnessing science and technology (S&T) for development, particularly in the agricultural sector. Two major continent-wide policy documents stand out in their articulation of the African vision for socio-economic development, through the adoption and utilization of science and technology for sustainable development. These are: the Lagos Plan of Action for the Economic Development of Africa, 1980-2000 (April 1980) and the AU/NEPAD policy document Africa's Science and Technology Consolidated Plan of Action (CPA) (November 2005). These documents have articulated African aspirations for acquiring, building, and strengthening capacity for utilization of scientific and technological knowledge and competencies for sustainable development (Adedeji, 1985; Mihyo, 2011).

The main thrust of the Lagos Plan Action (LPA) was to foster collective actions and programs for sustainable development in Africa by taking deliberate measures to promote increased self-reliance; accelerating internally located and relatively autonomous processes of growth; and diversifying social and economic activities based on scientific and technological knowledge and research. The LPA also advocated the democratization of the development process, progressive eradication of mass poverty and unemployment, and fair and just distribution of the incomes and benefits of development among the populace. In addition, the LPA emphasized the value of accelerated regional economic integration through cooperation and trade (Adedeji, 1985; Mihyo, 2011).

Building on past African experiences and ideas, the thrust of the AU-NEPAD Consolidated Science and Technology Plan of Action is to articulate Africa's broad "vision, objectives and commitment to collective actions to develop and use science and technology for the socio-economic transformation of the continent and its integration into the world economy." This rests on three pillars: capacity building, knowledge production, and technological innovation. The CPA has identified a number programs for research focus, among them biotechnology, biodiversity and indigenous knowledge, water, energy, information and communication technologies (ICTs), use of laser technologies, and mathematical and material sciences. Hence the CPA, very much like the LPA, is a rallying call for Africa to utilize scientific and technological knowledge and skills to release the full potential of its people and its endowment of abundant natural resources. In this way, the continent can liberate its people from the scourge of poverty, achieve the MDGs, and realize its cultural renaissance, while integrating into the global knowledge economy.

The role of S&T in Africa's socio-economic development is fully accepted and is no longer a matter of debate or pious declarations. The major concern is how to harness the power inherent therein (AU/NEPAD, 2007; ATPS, 2010; Hassan, 2009; Kamoun, 2011). A broad consensus has thus been reached to concentrate on the implementation of articulated policies and programs in order to acquire and utilize scientific and technological knowledge and skills. In this way, the commitments that African governments have made will be met. Such commitments include the implementation of Education For All (EFA), realization of the MDGs, and sustainable development. The realization of each requires building and marshalling of scientific and technological capacity.

Since its formation, the AU has built the political consensus needed to give priority and increased attention to the development of science and technology. These efforts have been accompanied by solid support from UN agencies, for instance UNESCO and UNECA. UNESCO in particular has taken leadership in supporting AU-NEPAD initiatives through the UN Science and Technology Cluster. For instance, it has launched the African Science, Technology and Innovation Policy Initiative (ASTIPI) to assess the status of science and technology policy formulation in Africa, provide technical advice and support for national science, technology, and innovation (STI) policy reviews and develop common African STI indicators. In addition, it supports creation of an African STI observatory.

The articulation of African policies, programs, and initiatives on STI undertaken at continental level, while a culmination of past regional and national efforts, has gone a long way to galvanize and reinforce policies and actions being made at regional, national and institutional levels. These are reviewed briefly below.

1.2 REGIONAL ECONOMIC COMMUNITIES

Regional economic communities (RECs) have also shown strong commitment to the promotion of S&T for socio-economic development in Africa. The continental vision for S&T is echoed in RECs, namely, the Common Market for Eastern and Southern African States (COMESA), the Economic Community of West African States (ECOWAS), the East African Community (EAC), and the Southern African Development Community (SADC). These regional entities not only have strong mandates in this field, but have also gone ahead to articulate and formulate regional policies and collaborative programs to realize STI in their respective regions (Mugabe, 2009; Mihyo, 2011).

International and regional institutions such as the World Bank, UNESCO, and AfDB have also indicated support for these efforts. In 2008, the AfDB introduced its Higher Education, Science and Technology Policy to guide engagement and funding of projects in this field.

A number of international and regional research institutions are hosted in various African countries, but with regional mandates. These have become centers of excellence (COEs) in their respective fields of research and development (Mugabe, 2009). Kenya is a host to a number of such important international institutions whose mandates are regional and international. These are the World Agroforestry Centre (ICRAF), the International Livestock Research Institute (ILRI), and the International Centre for Insect Physiology and Ecology (ICIPE). Research networks and institutes, such as the Africa Population and Health Research Center (APHRC), the African Centre for Technology Studies (ACTS), the African Technology Policy Studies Network (ATPS), and the African Academy of Sciences (AAS) are also located in Kenya. Similarly, South Africa hosts the International Centre for Genetic Engineering and Biotechnology (ICEGB), the African Institute of Mathematics and Science (AIMS), and the Southern African Biosciences Hub, among others.

Some of the networks and institutions work under the auspices of the AU and NEPAD. Among them are the African Biosciences Initiative (ABI), African Laser Centre (ALC) and the African Science, Technology and Innovation Indicators Initiative (ASTII) (AU/NEPAD, 2007; UNESCO, 2005).
These initiatives are intended to serve African countries and receive support not only from African governments hosting them but also from international development agencies. In many respects, they complement and supplement the efforts of national research systems and COEs being built within and outside higher education institutions throughout Africa (Mihyo, 2011).

1.3 ESTABLISHING NATIONAL PRIORITIES AND INITIATIVES

While AU and NEPAD have articulated continental objectives and regional economic communities have taken initiatives to the regional level, the articulation of national priorities and strategies remains the prerogative of national governments, ministries and institutions responsible for S&T. Ongoing Africa-wide initiatives and the initiatives of RECs cannot replace the critical role of national processes and plans.

At national level, each country tends to follow its own path in articulating scientific and technological priorities and strategies. In the past, each national council for science and technology had the mandate to articulate S&T strategies, programs, institutions, and innovation processes. However, more recently, this task has been taken up by the ministries responsible for S&T. In some countries, this is done through political statements, national vision documents, and strategic documents (UNESCO, 2010a; Mugabe, 2009). The vision documents of Ghana, Kenya, Nigeria, Rwanda, and Uganda, for instance, incorporate S&T strategies (Ghana Vision 2020; Kenya Vision 2030; Nigeria Vision 20: 2020; Rwanda Vision 2020; and Uganda Vision 2020).

A number of countries have indicated their priorities through documents such as development plans, white papers, and other strategic documents on science, technology and innovation. Mozambique and South Africa have tended to follow this path. In some countries, research priorities in S&T have been defined from a sectoral perspective, for instance in agriculture, biotechnology, and energy (Mugabe, 2009). Burkina Faso, Senegal and Uganda fall into this category. The resurgence of mineral trade has led to increased interest in pursuing scientific research and technologies related to development of mining. This interest is observable in Botswana, Liberia, Sierra Leone, Zambia, and Zimbabwe where mining and minerals are dominant economic activities.

In setting their priorities, some countries have adopted a process that brings stakeholders together to articulate a collective national vision and priorities of their countries. Where this has happened, the process has tended to mobilize support, create a sense of ownership, and build public awareness of the value of pursuing policies oriented towards the acquisition and utilization of S&T for development.

By and large, Africa needs to recognize that countries that have the most successful and persistent innovation records are often those that ensure consistency between their policies and actions. Finland, Japan, and South Korea are outstanding examples in this respect. In these countries, scientific and technological progress has been a national imperative and innovation policy has remained a permanent strand of government policies and actions.

1.4 EFFORTS AT INSTITUTIONAL AND PROGRAMMATIC LEVELS

In other instances, individual institutions responsible for research and higher education have tended to articulate their visions in anticipation of funding or as a strategy for rallying stakeholders to buy into declared intentions and development paths. Many higher education institutions (HEIs) have adopted this process as way of cultivating and demarcating the direction in which they intend to move and building consensus. This practice, which is commonly utilized in the private sector, has become widely adopted by research and higher education institutions.

1.5 EMERGING ISSUES AND EXPECTED ACTION POINTS

While most African countries recognize the usefulness of articulating policy, creating requisite institutions, building capacities, and promoting regional cooperation, there is need for increased and consistent investment in STI. However, these investments must demonstrate concrete and widespread benefits to people whose main concerns include food security, health care, water, energy, and sustainable livelihoods. This can be done through coherent implementation of national policies and programs; creation of relevant institutions; and building of requisite capacities for development, dissemination, and use of science and technology. In this way, national agendas can be realized while fulfilling agreed upon continental, regional, and international commitments. Hence, national ownership of policies and implementation strategies is critical to success (ATPS, 2010).

Despite good intentions, Africa is not adequately prepared to exploit the potential of STI in the development of its rich resources and its relatively youthful population (ATPS, 2010). This lack of preparedness will be discussed in other sections of this paper. To correct the prevailing situation Africa should:

- Make STI key to national visions. To do so, there is an urgent need to build awareness among national leaders, policy makers and other stakeholders on the significance of science and technology for present and future development. This should be followed by building the capacity of policy makers to formulate good policies, follow them through, and, where necessary, recognize good practices from elsewhere.
- Create a national observatory on STI in each country.
- Build capacity for the regular updating of scientific data to inform policymaking. Each national government should establish a science depository centre to keep scientific and technological research data for assessing the current situation and for future reference.
- Increase national coordination and funding for R&D to 1% of GDP as per continental and regional commitments.
- Establish systems for the monitoring and evaluation of agreed implementation strategies and processes.

1.6 WAY FORWARD

The articulation and promotion of policies, programs, institutions, and capacity building for the development of STI have been identified and analyzed at four levels: continental level (AU/ NEPAD, UNESCO, and UNECA; regional economic entities (COMESA, EAC, ECOWAS, SADC, and regional research institutions); national bodies (national science and technology councils, ministries, etc), and institutional level (universities, research institutions, and networks). In the process of formulating these policies and strategies, Africa has benefitted a great deal from international expertise and funding. These efforts are at different stages in various countries.

However, there is a need to take a more strategic and comprehensive view of science and technology. This is because, success in the development, diffusion, and utilization of science and technology is a complex enterprise, encompassing interaction of public and private players and institutions; education and training; cultural, socioeconomic, legal, and political dynamics; and processes at both local and global levels. For success at regional and national levels, science and technology policy formulation and implementation must address itself creatively and critically to these complexities. By doing so, Africa will positively enhance its potential and cease to have the most glaring barriers to the generation and utilization of knowledge for development (AfDB, 2008).

Moreover, there is an urgent need to institute mechanisms for monitoring and evaluation of progress made in the implementation of the agreed policies, strategies, and set targets. An assessment of the effectiveness and output of African institutions, scientists, and other professionals in science, technology and innovation needs to be undertaken at country and regional levels and international comparisons made. The CPA made a welcome recommendation in which it advocated for the establishment of ASTII for this purpose. This initiative, under the auspices of NEPAD, produced the African Innovative Outlook 2010, which covered 19 countries in all regions of the continent. This is a positive step towards creating systematic indicators for measuring the effectiveness of African efforts in turning policies and programs into tangible results (Kamoun, 2011). Previous efforts have been made to evaluate the output of Africa's scientific and technological communities and their overall impact on society, but these have been found wanting (UNESCO, 2010a; Pouris and Pouris, 2009). However, the work of ASTII will give rise to useful debates and eventually appropriate indicators to meet this important need. ■

02

FOUNDATIONS OF LIFELONG LEARNING OF SCIENCE AND TECHNOLOGY

In a world where scientific knowledge and technologies are changing rapidly and have a dramatic impact on socio-economic development, it is imperative that individuals not only acquire skills and knowledge for the present, but are empowered to continue learning and revitalizing their capacities to cope with these rapid changes. Such competencies and resilience are often referred to as lifelong education (World Bank, 2003). It embraces all aspects of human development, from childhood, through adolescence and into adulthood, and encompasses learning at household level, among peers, at school, and at the workplace. Such an education is gained through a process of interaction and encounters with other people and the physical environment. The ability to continue to learn as the world changes, knowledge increases, and technologies become more sophisticated is very critical to survival and sustainable development.

Hence, the acquisition of scientific and technological knowledge and skills does not take place in school alone, but is a process that embraces all aspects of growing up, and maturing, as well as interacting and communicating with other people, nature, and the environment. Failure to change as knowledge, skills, processes, and institutions change can lead to obsolescence, atrophy, and irrelevance in the society.

Two critical foundations for a lifelong process of acquisition, adoption, and utilization of scientific and technological knowledge and skills in Africa to improve livelihoods in a sustainable manner are indentified and discussed below. These are indigenous knowledge (IK) systems and the schooling system.

2.1 INDIGENOUS KNOWLEDGE

As Gorjestani (2000) argued, *"indigenous knowledge (IK) is used at the local level by communities as the basis for decisions pertaining to food security, human and animal health, education, natural resources management, and other vital activities."* IK therefore entails knowledge, practices, and skills embedded in local beliefs, customs, and cultural and spiritual values of communities that guide decisions and actions related to livelihood, interaction, utilization, and safeguarding of the environment. It also entails the process and methodologies of acquisition and transmission of IK on a continuous basis, as well as creative adoption and utilization in the changing circumstances of communities.

In the past two decades, indigenous knowledge has been recognized as a potent resource for tackling issues related to sustainable development, improvement of individual and communal welfare, empowering people, and providing an essential foundation for building firm ownership of development processes (World Bank, 2004; ATPS, 2010; AU/NEPAD, 2007).

The turnaround in the way in which development actors or practitioners view indigenous knowledge as an integral part of sustainable development has been remarkable, and has boosted research interests in this field. This rekindled interest in indigenous knowledge came after many decades of neglect, reviling, and marginalization. Development experts and scientists often ignored or reviled indigenous knowledge as a mechanism of knowing, understanding, and solving community problems. Today, this turnaround has brought a flurry of IK activities by international institutions, local civil societies and, communities. As former Tanzanian President Benjamin Mkapa acknowledged, in affirming support for IK, *"local solutions were even discriminated against as hindering progress, outdated, "old wives tales" or simply just unfashionable. As we "modernized" our societies, a "degree" in traditional indigenous knowledge was not planned for. Hence, we overlooked its potential as a resource and even further neglected the knowledge that women and men, families and communities had developed themselves for centuries"* (Mkapa, 2004).

The assault on indigenous knowledge was carried out through various channels such as religion, the education system, foreign languages, and other forms of domination. It is against this backdrop that the current revival of indigenous knowledge must be viewed and appreciated. The challenge is how to balance the often compelling forces of "modernization" while acknowledging that over the ages, communities have accumulated and utilized invaluable traditional knowledge in their attempt to shape and adapt to their environments.

The acquisition and transformation of this knowledge and related skills are embedded in the lives of communities as means of livelihood and sustainable development. IK is living and vibrant. It is essentially lifelong and adaptive to changing circumstances (World Bank, 2011a). The fact that it has survived parallel to the modernization tendencies of colonialism and westernization is an indication of its strength, flexibility, and relevance.

However, the ongoing revival and interest in indigenous knowledge must be incorporated into the learning and teaching methodologies, processes, and practice of science in schools. In this way, it will become an essential pillar for learning of scientific and technological knowledge and skills throughout the schooling system. More so, duality and tension between local community knowledge—the environment where students are brought up)—and what is taught in classrooms will be minimized. This is a challenge and an opportunity for integration and harmonious development of two approaches to the acquisition of scientific and technological knowledge relevant to sustainable development in Africa.

Where the language of instruction is the language of the community, this integration can be relatively smooth. The use of mother tongue as the initial language of instruction would go a long way in facilitating the integration of indigenous knowledge into school learning. This would also create opportunities for adult learners wishing to enhance their knowledge and skills, since many of them lack competency in the dominant languages of instruction in formal schools.

2.2 TEACHING AND LEARNING OF SCIENCE AND TECHNOLOGY IN SCHOOLS

The second foundation of lifelong learning and renewal of scientific and technological knowledge and skills is what is learnt through the formal schooling system. The critical element here is the teaching and learning of sciences. Teaching the appreciation of scientific methodologies and principles is perhaps better inculcated in the early stages of basic education if not done at household level (Juma *et al.*, 2005).

In this context, the role of the teacher is fundamental to cultivating an appreciation and mastery of the subjects, and especially mathematics and science. Hence, the quality of teaching is very important for attainment of the requisite knowledge, competencies, and behavior needed by students for success in further training and higher education.

The environment created for pupils to learn mathematics and science is also very important. It starts with the acknowledgement and appreciation of learning gained by learners in their families, among peers, and in the communities in which they live. The challenge to school management and teachers is to recognize the knowledge and skills that pupils bring along with them, and build on these by providing a quality learning environment in schools. Where teaching and learning in schools recognizes the knowledge in the community, then the process of schooling does not alienate students. This is the integration that we have argued above is needed throughout the schooling process.

For pupils to succeed in the acquisition of scientific and technological knowledge and skills necessary in society, learners need to interact with parents, communities, teachers, and the school environment. A rich school environment provides and appreciates the totality of the environment of the learner, the community, and the school. This is intended to incorporate the concept of "education through science' where the learner's environment is the laboratory (Holbrook, 2009).

Unfortunately, in Africa the teaching and learning environment that pupils encounter in schools is not often the best in terms of competence and qualification of teachers, availability of textbooks, classroom space, and laboratories. In addition, the dominant teaching methodologies are often not learner centered, are only minimally interactive, and rely on rote learning. Teaching and learning is oriented towards passing examinations. Parents, teachers, and students are fixated on doing well in examinations rather than learning practical skills.

At the basic level, students are confronted with poor quality teachers and learning environments. Learning is thus hampered and requisite knowledge and competencies are not achieved.

In this situation, the starting point is to recognize that pupils come from their environment with knowledge and skills available within their communities. These could be skills of language, numeracy, inquiry, and observation and overall knowledge of the environment in which they live. The school environment, through teachers and the management, can enhance the knowledge and skills that pupils bring from home to school and build on them. In many instances, school ignores this and proceeds to inculcate new knowledge, behavior, and skills.

Hence, the training, attitudes, and behavior of teachers in relation to IK are critical to the integration of home and school knowledge. Their creativity and innovation in this context are crucial to providing quality and relevant education and especially learning of mathematics and science. Moreover, the challenge of bringing together what is learnt at home and school and integrating this into school learning and continuing education needs to be critically addressed.

2.3 TEACHER EDUCATION

The quality of teaching and learning of science and technology hinges on the quality of teachers available at all levels. This is usually varied. In some schools, qualified teachers dominate while in others, poorly trained and unqualified teachers are common. Yet the foundation of advanced training in scientific and technological knowledge and skills is built at these early stages where teachers are engaged with the pupils in classrooms on a daily basis. This remains a major challenge to education systems in Africa.

In-service training for basic education teachers is undertaken at two levels: non-degree colleges, and degree granting colleges and universities. The quality and effectiveness of these programs are in many cases constrained by the caliber of students recruited, pedagogical exposure, and subject content provided while undergoing teacher education (World Bank, 2007; Kerre 2000). Overall, students recruited for training are academically weak, especially in mathematics and science. Again, while in training they are not given adequate exposure to subject content to prepare them to teach science (World Bank, 2007). Often, they get pedagogical training with minimal in-depth knowledge of the subjects they are expected to teach. One would expect these initial weaknesses to be rectified through subsequent professional development of teachers. However, these programs tend to be poorly funded and not sufficiently well planned to make real progress in improving the quality of teaching and learning in schools and especially in subjects such as language, mathematics, and science.

There is thus a need for policies and effective quality assurance mechanisms that integrate the process of recruitment, training, professional development, motivation and rewards system, and the status of science and technology teachers (World Bank, 2007; UNESCO, 2007a).

Tertiary education bears the major responsibility for pre-service training of teachers for basic and technical education. However, recruitment into these institutions is not often of students who have performed well in mathematics and sciences, but more often of those who cannot make it elsewhere.

While recruitment into teacher education and training of teachers is a major constraint in the provision of quality education at all levels, research to guide policy and interventions is also lacking. Research is required to understand in-depth the quality of teacher education provided in the institutions mandated to do so. This is particularly so for mathematics and science teachers.

For Africa to realize its vision of a science and technology driven society, it must break the cycle of recruiting poor students for teacher education, giving them insufficient or inappropriate teacher education, and then sending them out to prepare the future generations of scientists, technologists, and innovators. It is imperative that this vicious cycle is broken for Africa to build a firm foundation for scientific and technological advancement. Multi-prolonged policies and strategies for this should be articulated, starting with initial training coupled with professional development of those teachers who are motivated and are interested in improving their knowledge and skills.

In this regard, Africa needs to learn from Singapore. Within a generation, Singapore has moved from being an underdeveloped city state poor in natural resources to highly developed status through calculated investments in quality education. Recruitment for the teaching profession is from the top one third of the secondary school graduating class; training is rigorous; and after employment, teachers are entitled to 100 hours of professional development annually. In this way, teachers are exposed to cutting edge knowledge and teaching skills (Vivien, 2012). This has turned teaching into a high status and well rewarded profession, a development also notable in South Korea (Korea Day presentations, 2012).

In comparison, the teaching profession in Africa is characterized by low status, poor remuneration, and poorly motivated personnel. Yet these are the people given the responsibility of nurturing the future generations of scientists and technologists. These professionals are often on the lookout for what they consider better opportunities elsewhere. This leads to a hemorrhage of teaching skills within the teaching profession. Students, especially girls, who survive this process must indeed be intelligent, committed, and determined to overcome and succeed.

2.4 EXPECTED ACTION POINTS

- Articulation of policies and strategies for capacity building of science and mathematics teachers: pre-service, in-service and continuous profession development focusing on subject content (incorporating IK), pedagogy, and practice.
- Increased attention to research on the status of science education at all levels: content, pedagogy, and practice.
- Increased quality of teaching profession recruits. The quality of science education in Africa will ultimately depend on the quality of those recruited for teacher education, of in-service training, and of professional development provided, especially for mathematics and science teachers, and on numbers to meet current and future demand for rapidly increasing enrolments.
- Use of ICT and Internet in teaching and learning. ICTs enhance access to and dissemination of information as well reduce time and cost. A number of African countries, including Kenya and Rwanda, have embraced ICT and incorporated it into primary schools as a part of enhancing scientific literacy and building positive attitudes to technology.
- Quality assurance mechanisms. These should be used to validate and certify skills and knowledge acquired, accrediting institutions, and making information available. ■

03

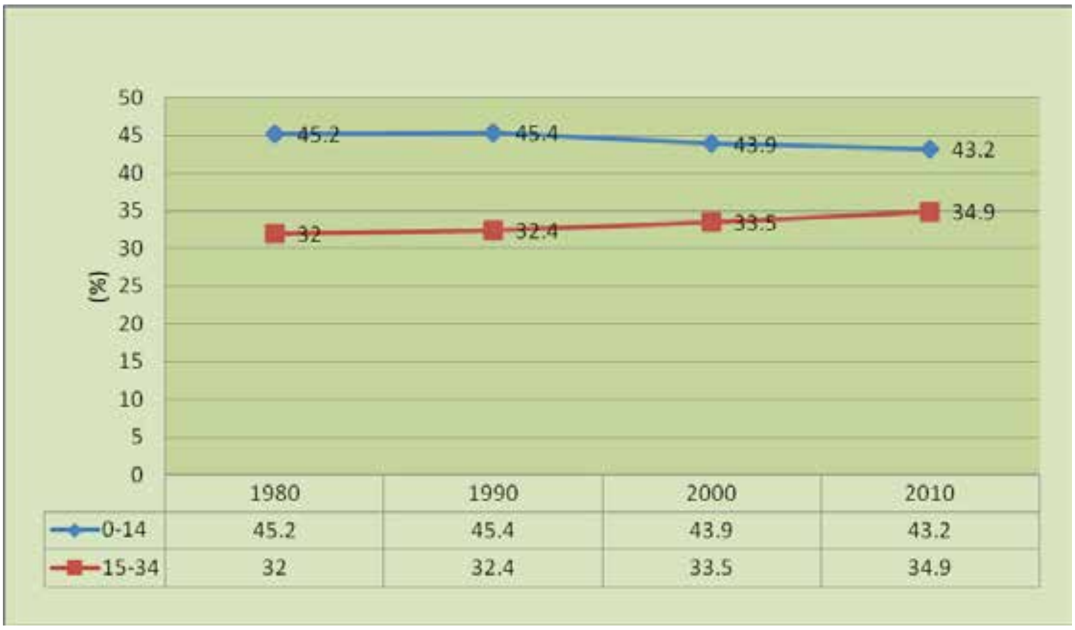
PREPARING AFRICAN YOUTH FOR SCIENCE AND TECHNOLOGY ENDEAVORS

The term "youth" is complex, assuming multiple meanings in different organizational and cultural contexts. In some situations, youth refers to a population categorized by age, while in other situations, youth is considered as a "problematic" stage in human growth and development (Sommers, 2001). In most African societies, the youth are "commonly perceived in the process of becoming rather than being" (Diouf, 2003; Boeck & Honwana, 2005), perhaps because they are perceived as "young" and not fully adult.

In practice, and depending on intended purpose(s), regional and international organizations define the term by specifying varying age categories of youth. UN agencies such as the International Labour Organization (ILO) define youth "as those aged 15-24 years". We find this definition too restrictive in Africa. It excludes a critical mass of young people at different stages of development, in and out of education and training institutions, and going through various transitions. Some are transiting from childhood to adulthood, from basic education and training to higher education, and from school to the labor market (Youth Consultation, 2011). Hence, in this context, we have adopted a definition of youth that is favored by the AU and is more embracing; it includes all those below 34 years of age.

By any definition, youth constitute a large proportion of the population in Sub-Saharan Africa. In 2010, the total African population was estimated at 867 million, with children aged 0-14 years constituting 43.2%, while young people aged 15-34 years accounted for 34.9%. Those above 35 years made up 22% of the population (see Figure 1). However, according to the United Nations Population Fund (UNFPA) 2011 report, Africa's population surpassed 1 billion people in 2009 and is projected to increase to 2 billion by 2040. This population will remain relatively young, however, as fertility in most African countries is unlikely to change

Figure 1: Growth of the youth population in Sub-Saharan Africa, 1980-2010



Sources: United Nations; World Population Prospects cited in World Youth Report (2007); Population Reference Bureau, 2010; TradingEconomics.com.

dramatically in the next three decades. Population projections show that by 2030, nearly a quarter of the world's youth will be African, and by 2040 Africa will have the largest working population, surpassing today's giants, India and China (Nzau-Mutete, 2012).

According to Gavin (2007), "Africa is currently in the midst of what demographers call 'a youth bulge,' indicating a significant increase of young people in the structure of population". The impact of this youthful population on current and future developments in Africa is worth a close analysis. Unless meaningful national policies and measures are put in place to guide and utilize the potential young people represent, the projected growth will exacerbate youth unemployment and poverty levels in the region, leading to entrenchment of hopelessness and instability. This situation could explode into violent struggles as the youth challenge the existing institutional, economic and political arrangements. The rumblings of discontent are already being felt in many African countries.

3.1 PREPARING FOR THE YOUTH BULGE DIVIDEND

Youth in Africa are generally marginalized and allocated limited space and resources (Chinguta, 2002; Deborah, 2004; Boeck and Honwana, 2005; Comaroff and Comaroff, 2005). This category of the population is characterized by a high dependency rate requiring high investments in education, healthcare and jobs. The youth are in various forms of transition. They are migrating in large numbers from rural to urban informal settlements in search of better opportunities (UNFPA, 2011; 2007). They make up 40% of the African working population but 60% of them are unemployed or underemployed, many being engaged in survival activities in the informal sector (World Bank, 2009a). The share of unemployed youth among the total unemployed can be as high as 83% such as in Uganda, 68% as in Zimbabwe and 56% as in Burkina Faso. Youth unemployment in Tunisia stood at 14.2% in 2010. It was more pronounced among young graduates with Masters Degree in law, economics and management, estimated at 47% within this group in 2007 (Stampini and Verdier-Chouchane, 2011).

These young people are better educated than their parents in relative terms, and are well connected through the use of mobile phones and the Internet. They are well informed of the technological advances being realized globally, but often lack formal employment or entrepreneurship opportunities. Hence, access to and utilization of available technologies for productive activities in their environment is limited. On the whole, young people are looking for better education, training, skills, and opportunities to be productively engaged (UNECA, 2011; UN, 2010).

If well taken care of by investing in the acquisition of scientific and technological knowledge and skills through quality education at all levels, health care, and democratic and visionary leadership, the youth bulge in Africa offers great opportunity for the continent to turn its rich natural resources into the basis for economic growth, employment creation, and sustainable development (Gidoomal, 2011; ATPS, 2010). The challenge of the youth bulge is to see how young people can become a force for transformation of the current situation into a future where their energies are utilized to unlock the wealth in their countries. When denied these opportunities, they can become a potent force of frustrated and angry missiles for violence, crime, and unruly behavior. Experiences in DRC, Guinea, Ivory Coast, Liberia, Mali, Nigeria, Sierra Leone, and Somalia, and indeed in North Africa, are a pointer to the urgent need for proactive policies and initiatives targeting the youth.

African countries therefore need to analyze how the AU/NEPAD CPA could become a platform for articulating pro-youth policies, programs, institutions, and capacity building targeting a wide spectrum of youth, in addition to those enrolled in the formal education system. In this way, countries would respond appropriately to the needs of out-of-school youth, those who leave school early, and graduates unable to find jobs.

Until recently, African youth were largely excluded from key decision-making structures and processes (Comaroff and Comaroff, 2005). Also, due to their jobless state, African youth face challenges in accessing positions of leadership and decision-making in the economy and community, education and training, health care, and acquisition of scientific and technological skills.

An assessment of youth programs initiated in a number of African countries to respond to youth unemployment, underemployment, and lack of scientific and technological skills indicates that most of the time, policy makers do not give adequate attention to the diversity of youth needs. Indeed, a typical policy response has been to raise educational levels and increase enrollments in higher education programs. This has not always yielded the expected results, as witnessed in North Africa. In 2007, youth unemployment in Tunisia was 20% among those without diplomas, 30% for secondary school diploma holders, and close to 50% among those with advanced degrees in economics, management and law (Stampini and Verdier-Chouchane, 2011).

Despite the gloomy situation, efforts are being made by organizations like ATPS to address the existing deficit in scientific and technological capacities among the youth and women. However, these initiatives are minuscule given the vast numbers of youth in Africa (ATPS, 2010).

We would like to argue that a comprehensive youth policy that takes into consideration the heterogeneity and diversity of youth needs should be articulated in each country. Since three quarters of the population in each country is made up of youth, national policies, including scientific and technological policies, should be geared towards this group. The youth population will become the African middle class in a few years' time and drive political, economic, scientific, and technological agendas (McKinsey, 2010; AfDB, 2011).

Table 1 shows differentiation among the youth and the need for differentiated and specific responses for each category of youth. Comprehensive and differentiated responses should take into consideration all youth irrespective of whether they are in school, training, formal or informal employment, or not engaged at all. Countries and other stakeholders targeting youth in a differentiated manner can expect to benefit from the youth bulge dividend as these young people become entrenched in development processes.

3.2 INFRASTRUCTURE AND LIFELONG LEARNING FOR YOUTH DEVELOPMENT

A key challenge is to provide infrastructure for promoting the acquisition of the scientific and technological skills needed for entrepreneurship and competition in the labor market as the economy grows and new jobs emerge (Youth Consultation, 2011; Africa Commission, 2009; ATPS, 2010). Hence, continuous learning and retooling should be the strategy for dealing with the existing shortage of skilled manpower while large numbers of young people are in search of work. While retooling and training approaches assume the availability of jobs and opportunities for productive engagement, the situation is often not the case. As such, African countries need to interrogate their economic policies and strategies to determine how they can contribute to employment creation. High rates of economic growth without job creation will not assuage the desperation of the youth.

3.3 CREATING AN ENABLING ENVIRONMENT: POLICIES, INSTITUTIONS AND PRIVATE SECTOR

National governments should increase resources and intensify efforts to support young innovators and entrepreneurs, irrespective of their educational backgrounds. As indicated earlier, youth in the informal sector should be availed funds and training opportunities to renew their capacities and engagement in projects and activities that require scientific and technological skills and competencies.

Governments should establish mechanisms and institutions for promoting innovations among the youth. This would motivate young people to engage or be engaged at different levels of research and development. Such mechanisms and institutions would become essential platforms for young innovators and entrepreneurs to learn, share, interact, and inform policy makers on policy directions for innovations geared towards creation of youth employment and wealth creation within the ambit of sustainable development.

There is also a need to enhance the commercialization of innovation through the entrenchment of global best practices regarding intellectual property rights, technopreneurship, and financial support and use. Additionally, governments must create an enabling business environment through incentive systems such as the creation of technology hubs, tax breaks on new ventures, and local procurement of technologies. Such procurement is critical considering that governments in Africa remain the single biggest buyer of goods and services. The importance of such procurement policies can be demonstrated in Kenya where the government spends about 70% of its annual budget on procurement. Currently, this amounts to 1 trillion Kenya shillings. In order to enhance youth entrepreneurship and employment, the government has adopted a policy that allocates 30% of public procurement to youth owned enterprises. This translates to over 300 billion Kenya shillings for the 2013-2014 financial year and, if properly executed, it "will create the new crop of digital African businessmen who will propel [Kenya] towards attaining and sustaining the Vision 2030" (Oanda, 2013).

With regard to young people emerging from conflict situations, national governments should redefine second-chance programs to include acquisition of scientific and technological skills and knowledge as core elements for the integration of these young people into their communities and reconstruction of the society. Conflicts and wars in some parts of Africa have destroyed not only the economy but also rendered the young population unskilled, idle, and poor. The majority of the youth missed out on schooling opportunities, becoming unskilled, unproductive, and unemployable. Redefining second- chance programs for youth at risk of violence and those emerging from conflict situations offers great opportunity to prepare them for lifelong acquisition of the relevant skills and competencies necessary for gainful engagement or employment.

The role of the private sector in stimulating economic growth is well recognized, though this is still underdeveloped in many African countries. We need to recognize the limits and constraints that the private sector faces in creating employment—cost and availability of skilled labor, need to maximize on the benefits of technology, costs of production, global competition, etc. Yet in partnership with the public sector, the private sector can become a creative channel for the acquisition of the skills and learning needed for employment in the first instance, as well as for entrepreneurship among young graduates. Such partnership will differ according to the circumstances

Table 1: Differentiated youth and diversity of responses

Location of youth in socio-economic development	Existing responses	Interventions to strengthen scientific and technological capacity
In-school youth: pre-school, primary, secondary, tertiary	• EFA • MDGs • Free primary education	• Improve teacher education in science subjects • Develop relevant and quality curriculum and integrate indigenous knowledge • Improve performance at all levels • Increase enrollments in science-based courses in tertiary education • Strengthen post-graduate training programs • Increase funding for research and development Enhance mechanisms for assessment and quality assurance • Strengthen university-industrial linkages
Youth out of formal education into skills training	Revitalization of differentiated national technical and vocational training system	• Improve infrastructure, curriculum reforms for TVSD • Strengthen public-private partnerships for skills development, apprenticeships, internships, and attachments
Youth in employment: formal, informal	Increased economic growth resulting from macro-economic reforms, pro-business policies, investments, and development of the informal economy	• Retooling • Improve ICT infrastructure • Leadership and governance training • Integration of S&T in youth policies and programs Enhance public-private partnerships • Improve access to capital
Youth not engaged	• Public works programs (*Kazi Kwa Vijana*) • Job placement programs (ministry of labor in partnership with ministry of youth and sports) • Youth policies: creation of ministries for youth • Fund for youth enterprises	• Non-formal education geared to scientific and technological literacy • Demobilization from conflict situations through technical skills formation and continuing learning (lifelong learning) • Establishment of microfinance programs • Creation of innovation hubs through private and public funding

Source: Authors, 2012

prevailing in each country. This requires creative dialogue between the public and private sectors on ways and means of improving job creation in the economy.

3.4 EMERGING ISSUES AND ACTION POINTS

- Articulation and implementation of comprehensive and inclusive economic policies and mechanisms to build the scientific, technological, and entrepreneurial capacities of the youth for the socio-economic transformation of African societies.
- Government-initiated expansion of opportunities for scientific and technological exchanges, especially among graduate students and young scientists, regionally and through south-south linkages.
- Widen opportunities for young scientists to access research funds and fellowships for further studies and improve their capacities for research and innovation.
- Improve ICT infrastructure at all levels to facilitate access to knowledge acquisition, creativity, and innovation among the youth.
- Create partnerships for science and technology involving national governments, RECs, the private sector, international agencies, civil society institutions, and grassroots communities science parks.
- Establishment of science and technology hubs where youth trained in a given field can access government developed infrastructure required to research and develop technologies. Such hubs allow for peer learning, knowledge sharing, incubation of ideas, and nascent technologies.

3.5 WAY FORWARD

Since young people constitute more than two thirds of the population in Africa—about 78% in 2010—it is imperative that their energy, creativity, and capacity for innovation are harnessed for sustainable cultural, socio-economic, and political development in Africa. Africa needs to go beyond provision of formal education and training opportunities to young people to critically reflect on what happens to them after they leave school and how economic growth caters for their needs and aspirations.

Moreover, youth policies should go beyond focusing on the relatively privileged few in the formal education system and fully embrace out-of-school youth. Indeed, non-formal learning must be given adequate attention in light of the low transition rates from one level of education to the next. These youth subsequently acquire knowledge and skills through non-formal means such as apprenticeship and on-the-job learning. Policies and mechanisms are thus needed for the recognition and validation of non-formal learning in order to facilitate re-entry into formal education and access to employment, and to enhance self-directed lifelong acquisition of knowledge and skills. In this regard, African countries should learn from global initiatives whereby non-formal and informal learning is validated (Werquin, 2010).

Another area of focus should be the informal sector. Data shows that 80-90% of the productive sector in Africa is composed of informal enterprises and in the next ten years this sector will remain the main job provider. Rather than treating the sector as an off-shoot of failures in the formal economy, governments should create a robust environment to enable it to thrive. The priority should therefore be to keep the sector productive and attractive to the increasing number of science and technology graduates (Nzau-Mutete, 2012). Eventually, the involvement of skilled persons and the use of technology will lead to increased productivity, employment creation, and professionalization of this critical sector.

Essentially, the challenge is to take a holistic and lifelong approach to societal acquisition and adoption of scientific and technological knowledge and skills for innovation, value-addition to natural resources, and overall wealth creation for the majority of the population. The achievement of the MDGs is central to this approach. Hence, holistic youth development should be central to any country's vision and development strategy. It should also be the core of strategies and programs geared towards the advancement of scientific and technological capacity of young people and society. In this way, Africa would benefit from the demographic bulge observed earlier in this paper. The report of the ADEA Youth Consultation highlighted actions that could be taken to bring youth to the center of development. Ignoring the youth potential denies Africa its most precious resource for sustainable development. ■

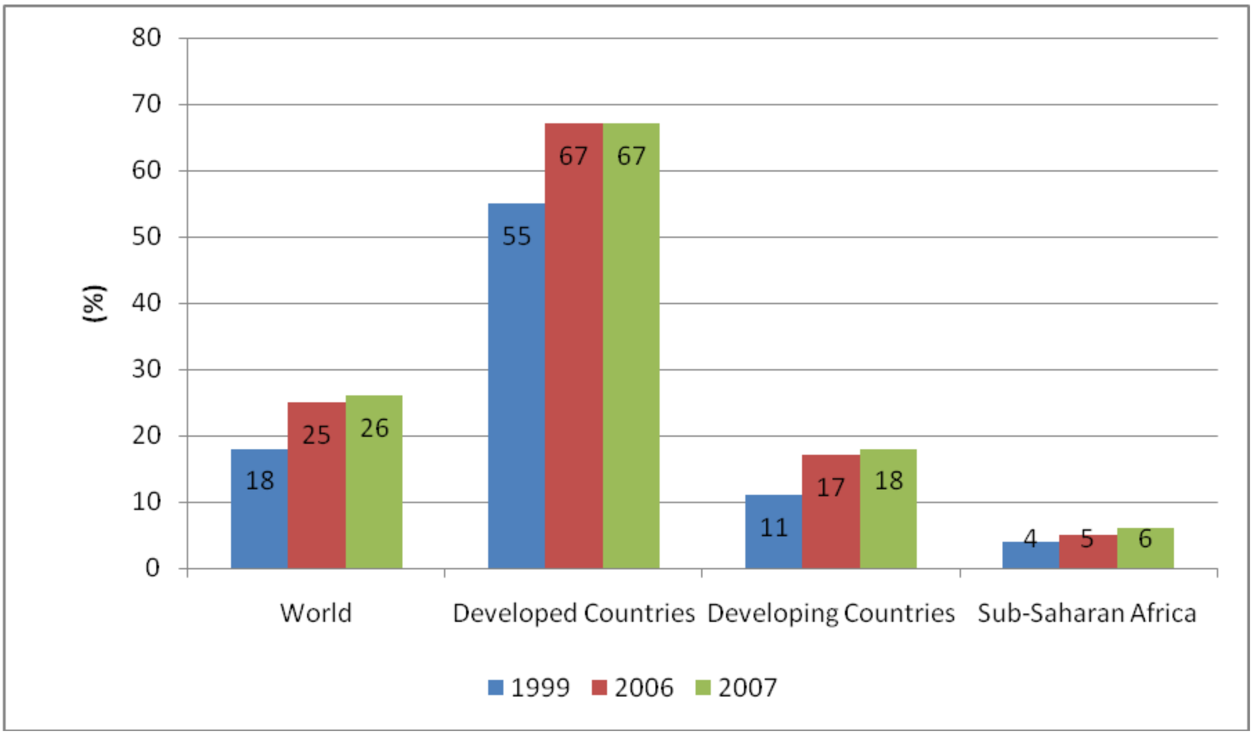
04

TERTIARY INSTITUTIONS: RESEARCH, INNOVATIONS AND LINKAGES

Tertiary education is highly valued in Africa. Competition for the places available is very intense. The proportion of household income and national budgets allocated to tertiary education is indicative of the high demand. However, despite the rapid expansion of tertiary education institutions in the past two decades and increased resources allocated to this, Africa remains the region in the world with the lowest proportion of higher education cohorts accessing tertiary education. In 2011, only 6% of the appropriate age cohort was able to access higher education (Figure 2). Although this was a slight increase from 5% in 2005 (UNESCO, 2011; World Bank, 2009b), Africa remains well below other regions, where in some cases the appropriate age group accessing higher education is over 60% (UNESCO, 2011). The global average is about 25% (World Bank, 2011). Africa is far from providing adequate opportunities to those who need tertiary education. The intense competition for the available places has also led to an increased number of students seeking educational opportunities in Asia, Australia, Europe, and North America (Varghese, 2008). Within Africa, this phenomenon is also common, with countries like Ghana, South Africa, and Uganda being preferred destinations.

Nevertheless, it should be recognized that the proportion of age cohorts accessing higher education in a number of countries such as Mauritius, South Africa, and Tunisia is above the regional average. Moreover, in terms of equitable access, we need to recognize that only a small proportion of African youth aged 18 to 24 are

Figure 2: Gross enrolment ratio (GER) in tertiary education in 1999, 2006, and 2007



Source: UNESCO 2009; 2010b.

accessing higher education (World Bank 2009b). This is despite an annual expansion of 8.7% in enrollments compared to the global average of 5.1%. Enrollments at tertiary level in Sub-Saharan Africa (SSA) almost doubled between 1999 and 2007, rising from 2,136,000 to 4,140,000 (Altbach and Salmi, 2011; UNESCO, 2009 and 2010b). This figure is now estimated at about 6.5 million. It should be noted that the bulk of students are enrolled in social sciences and humanities. Although these subject areas are important, there is need for a concerted reorientation towards science and technology.

In Africa, tertiary institutions are critical to socio-economic development as they represent a concentration of resources and talent (staff and students). African countries have invested in a number of public universities as a matter of national pride and for training of high level manpower. These institutions are also critical players in the research and development enterprise in their respective countries (Mohamedbhai, 2011). They host important laboratories and centers of innovation. In many countries, they are an integral part of the national research and innovation system. In light of this, the quality of education provided and research undertaken in these institutions is critical to the realization of national, regional, and continental S&T objectives (Kamoun, 2011 and Diarra, 2011).

Below we highlight some aspects of tertiary education that are critical to the utilization of the available capacities for the development and application of scientific and technological knowledge and innovation in Africa. The issues are: the impact of the expansion of tertiary education; the quality of education provided, especially scientific and technological education; the concept of centers of excellence; and university-industry linkages.

4.1 EXPANSION OF TERTIARY EDUCATION

The growth of tertiary institutions in Africa in the past two decades has been remarkable. The number of institutions is currently over 650—200 public and 468 private—and is increasing. Private sector providers have established themselves as important players in the provision of learning opportunities at the tertiary level, accounting for about 18% of total enrollments in the Africa (World Bank 2009b). Notably, the expansion of private universities in three East African countries (Kenya, Tanzania, and Uganda) over the past eight years has been impressive. In 2003, there were 15 public universities compared to 40 private universities, while in 2011 the numbers had risen to 21 and 76 respectively. These data do not include constituency colleges and institutes which will eventually become fully fledged universities.

While private universities in the three countries continue to grow at a higher rate than public ones, student enrollments in private institutions remain low. Public universities remain dominant in terms of diversity of their academic programs, affordability, public funding, research infrastructure, and the overall quality of staff and student body.

The current expansion of tertiary education is fuelled by an almost insatiable demand for tertiary education by the ever-increasing number of secondary school graduates and adults interested in improving their qualifications. Rising qualifications criteria for jobs necessitate acquisition of more knowledge and skills to compete for the limited opportunities in the labor market. Although the expansion of tertiary education has barely met the existing social demand, it has strained resources, infrastructure, and staff in both private and public universities.

Higher education institutions have therefore resorted to income generation through commercialization and "vocationalization" of university programs. Additionally, they have turned to entrepreneurial activities to boost their income amidst reduced government support for the sub-sector (Bok, 2003; Mamdani, 2007). This commercialization has led to the establishment of parallel degree programs for qualified students who miss out on admission to public HEIs during the highly competitive merit based selection and are willing to fully sponsor their studies. However, this trend tends to compromise the quality of student intake and, subsequently, learning and teaching processes (PUIB, 2006). As a result, the challenge of balancing quantity with the quality of education provided remains a serious concern.

Intense competition for a limited number of quality staff has often led to recruitment of academic staff without requisite qualifications such as PhDs. A straddling phenomenon has therefore emerged whereby staff employed in public universities constantly travel from their primary employer to teach in private universities to supplement their incomes. Private universities in turn recruit part-time staff to meet staff deficits and minimize on personnel costs. Overall, staff development and post-graduate training in many HEIs has received minimal attention (Kinyanjui, 2010). The situation of inadequate and unqualified staff, often overwhelmed by a heavy teaching workload, leaves no time for research.

The expansion of tertiary education has also led to a situation of overcrowding in lecture rooms and libraries, limited access to ICT, and, for students taking science subjects, minimal exposure and access to laboratories for practical lessons. The situation of African universities has been analyzed extensively by individual researchers, donor agencies, regional organizations, networks (including the Association of African Universities (AAU), AfDB, UNESCO, etc.), and African governments (Diarra, 2011). The outcomes of these studies need not be repeated in this paper.

The changing higher education landscape in Africa to a large extent reflects the emerging realization of the benefits that can accrue to the continent through enhanced global competitiveness and participation in the knowledge economy. At national level, this change is driven by demand for improved qualifications by individuals in order to compete for promotion and the limited jobs in the labor market. In addition, there is a pronounced need to redirect education and training of youth and adults towards acquiring the scientific and technological knowledge and skills necessary for unlocking Africa's economic potential and reaping the benefits of integration into the global economy (World Bank, 2003 and 2009b; PHEA, 2008).

4.2 STRENGTHENING CAPACITY FOR SCIENCE AND TECHNOLOGY IN TERTIARY INSTITUTIONS

On the whole, the expansion of higher education, particularly in SSA, has not given appropriate weight to STI. As observed, most of the enrolments in African universities and in particular in private universities are in the social sciences and humanities. Social sciences and humanities also continue to receive the biggest slice of the budget. As a result, investments in science and technology courses are limited (Juma et.al, 2005; PUIB, 2006; World Bank, 2009b).

There is an urgent need to reorient African universities and other tertiary institutions towards science and technology to bring out the much needed balance between social sciences and humanities offerings, and science and science-based courses and professions. This will enable Africa to achieve global competitiveness and value-addition to its commodities (Kamoun, 2011). The required balance cannot be achieved without reforms in secondary education to improve the quality of education and in particular performance in mathematics and science. The changes expected are gradual and long term, but remedial programs are required in the meantime.

Scientific and technological capacities which are needed at this juncture to unlock the potential of African natural resources cannot be realized without radical restructuring and reorientation of universities to focus on increased numbers and output of scientists, engineers, and technologists. Increased research output and innovations are of essence. This remains a critical challenge for the continent as evaluation of African outputs in terms of publications, journals, patents, innovations, and other indices shows that these outputs remain minuscule compared to other regions (Kamoun, 2011).

Issues that need urgent attention are: increased national funding of research; reduction of heavy teaching loads to allow staff to engage in quality research; minimizing of dependency on donors; management of consultancy and individualization of research enterprise; installation of up-to-date equipment, facilities, and research laboratories; and increased resource allocation to graduate education to replace aging intellectuals while building academic communities through peer mentoring and review. Additionally, access to ICT and journals is critical to uplifting research standards in African universities and institutes.

4.3 TOWARDS A DIFFERENTIATED TERTIARY EDUCATION

The ongoing expansions at tertiary level must be differentiated in order to provide a diversity of knowledge, competencies, and skills requirements in growing economies, and to cater for different student abilities and needs. Institutional specialization and concentration is required.

This kind of differentiation could cater for excellence in R&D and benefit from concentrated pools of talent. Given the limited resources available for higher education, differentiation is necessary for efficient utilization of resources for R&D, modernization of infrastructure, graduate training, and capacity building of talented scientists and researchers (Hörig, 2011; Kuria et.al, 2011; World Bank, 2009b).

The nature of expansion of tertiary institutions in many African countries tends to undermine development of middle level institutions that produce technologists, technicians, artisans, and other sub-professionals to meet the needs of the economy and complement skilled graduates, scientists, and engineers. To address this problem, a balanced development of tertiary education to meet the needs of the economy is therefore necessary. Consequently, a policy rethink on the current approaches to increasing places in higher education is urgent.

There is no question that Africa requires differentiated universities, training colleges, research institutes, polytechnics, and other tertiary institutions to meet its scientific and technological advancement and other developmental needs. The tendency for institutions to be everything to everyone does not augur well for quality outputs, specialization, and innovation. The case studies undertaken under the auspices of study on the *Role of Tertiary Education Institutions in the Development of Technical and Technological Capabilities for Employment Creation* have demonstrated the value of institutional differentiation in Ghana and Namibia.

4.4 THE CHALLENGE OF QUALITY AND QUALITY ASSURANCE

The quality of the rapidly expanding tertiary education in Africa has been the subject of several studies (AU, 2007; World Bank, 2009b and 2000; Sabaya, 2004). There is near consensus that accreditation processes are weak, leading to the introduction of courses in fields such as engineering, medicine and law that do not meet required standards or the approval of professional bodies. Such courses tend to attract fee-paying students interested in entering high status professions.

Needless to say, not all universities are providing poor quality courses and programs. Across Africa, there are universities delivering excellent teaching, research, and community service, although in global rankings they do not necessarily reach the top tier.

A study by the German Academic Exchange Service (DAAD) and the Inter-University Council of East Africa (IUCEA) entitled *Regional Cooperation for Quality Assurance: The IUCEA/DAAD East African Quality Assurance Initiative* made some significant findings. It underscored the need for universities and tertiary institutions as a whole to internalize QA mechanisms focusing on students, courses offered, teaching and learning process, and expected results. The study also emphasized the need to strengthen national regulatory bodies as well as regional cooperation and collaboration in QA.

The value of this kind of regional cooperation as well as the need for informed leadership and legal and financial support at regional level for sustainability of these kinds of interventions beyond donor funding should not be underestimated. The study underlined that comprehensive, independent, and effective QA in both public and private universities is essential for the acquisition of high quality scientific and technological knowledge and skills. Investing in internal and external mechanisms for QA is therefore vital for Africa if production of quality research and innovations needed for socio-economic development is to be guaranteed (AU, 2007; Sabaya, 2004). Other regions can build on the lessons and experiences gained in East Africa (IUCEA/DAAD, 2011).

It has been observed that the poor quality of teacher education provided at tertiary level tends to be manifested in poor teaching and learning of mathematics and sciences at lower levels of education. There is need to improve the quality of in-service training of teachers in all tertiary institutions. Effective QA mechanisms can help in identifying specific needs and appropriate interventions (see section 2.3 above).

The ADEA Youth Consultation held in 2011 emphasized this concern by indicating the need to uplift the overall quality of education provided at lower levels of the education system in Africa. In this way, the cycle of poor students being recruited into teacher education institutions and then returning poorly equipped into the teaching profession can be broken. Quality assurance should be extended to professional development of science and technical teachers as a priority.

4.5 RELEVANCE AND EFFICIENCY

Strengthening of scientific skills in the higher education sector must focus on relevance. In the past, the relevance of an educational system was equated with quality, and quality was in turn judged according to theoretical principles. Today, the conception of quality has changed; it is now perceived as the mastery of specific skills that match the ambitions of the country or the region where the university is located. We must move beyond the teaching of science as a separate discipline in universities and towards the adoption of an approach that fosters a "scientific culture" that also embraces efficiency and accountability in the use of available resources.

As African countries invest more resources in education, there are persistent concerns about the relevance of the curriculum offered and the overall efficiency and effectiveness of the governance and management of tertiary institutions. Experiences in Egypt, Libya, and Tunisia have shown that despite heavy investment and the rapid expansion of primary, secondary, and tertiary education, these institutions are producing graduates lacking the skills needed in the economy.

4.6 BUILDING CENTERS OF EXCELLENCE IN SCIENCE AND TECHNOLOGY

A continuing challenge is not only to improve the overall quality of education and professional training in African universities but also to create centers of excellence (COEs) in post-graduate training, post-doctoral exposure, and R&D. Efforts geared towards this are notable at national, regional and international levels. The establishment of the African Institute of Science and Technology (AISTI) and the proposed Pan-African University are initiatives intended to harness Africa's talent in a collaborative manner by utilizing limited resources effectively through concentrated endeavor in critical and strategic fields of development (Namata, 2012).

It is, however, important to recognize that opinions are varied on the value and modalities of operation of COEs in Africa. It is in this context that the DAAD initiative to start five Africa-German COEs should be evaluated. The objectives of the initiative are to pursue capacity building, strengthen educational quality, and improve research output in the cooperating universities. These efforts are bringing German experiences to a number of African universities—to build capacities in micro-finance in DRC, logistics and transport in Namibia, postgraduate studies in law in Tanzania, research and criminal justice in South Africa, and development studies and health research in Ghana.

A study focusing on the concept of COEs and experiences gained in the five collaborative projects was prepared for the 2012 ADEA Triennale to stimulate discussion and sharing on how COEs can strengthen African universities' capacities in research and postgraduate training. Where these initiatives have been taken, a lingering question is how to measure their success and whether reliance on donor support has a biased bearing on the research priorities. Indicators of success, like in other S&T institutions, should be determined to accompany the interventions. Furthermore, though the idea of COEs is alive, it is hardly settled despite the many and varied exchanges on the continent (Nordling, 2009; Mugabe, 2008; AU/NEPAD, 2007; Urama et.al, 2010)

4.7 UNIVERSITY-INDUSTRY LINKAGES: THE CHALLENGE AND THE PROMISE

A great deal of interest has emerged on the issue of linking universities to productive sectors of the economy (Kruss, 2006, AAU and AUCC, 2011). Two contributions were prepared on this topic for the Triennale: AAU and the Association of Universities and Colleges of Canada (AUCC) prepared a paper entitled *Strengthening Linkages between Industry and Higher Education Institutions in Africa* while a team headed by Paschal Mihyo prepared a contribution entitled *The Role of Tertiary Education Institutions in the Development of Technical and Technological Capabilities for Employment Creation in Eastern, Southern and West Africa: Selected Case Studies.* Both studies focused on various dimensions of this complex relationship. Their conclusions include the following:

- A definition of what constitutes university-industry linkages should be tailor-made to African economies, especially the informal sector where the size of industries is often small and production is for a limited market. However, the interests of various players—government, universities, and economic actors—should be incorporated.
- University-industry linkages are most notable in agriculture and agribusiness, ICTs, environmental management, computer engineering, and banking. It was noted that there was less collaboration in the manufacturing, pharmaceutical, mining, and entertainment sectors.
- While oil and mineral extraction activities account for a large proportion of productive sector activities in a number of African economies, there are practically no discernible university-industry linkages.
- Few universities have established science parks and technology incubators where they could showcase their research findings and innovations to interested entrepreneurs.
- Universities should articulate policies and rules to guide and govern the complexities of the relationships between them and productive sectors.

The papers also recommended radical changes in how universities relate to various players in the economic sector to improve collaboration, dissemination, and adoption of innovations emanating from research findings. This paper cannot do justice to the insights the two studies provide into this important topic. However, we would like to draw the attention of policy makers and researchers to the changes required in policies, mindset, and management structures in the universities to facilitate dialogue and sharing of experiences with the productive sectors of the economy in order to enrich linkages between universities and key players in the economy. The study by AAU and AUCC thus argued:

> *Creating a conducive, enabling environment for supporting linkages with the productive sector requires a multidimensional approach...*

> *Strengthening linkages with the productive sector should ideally go hand in hand with parallel efforts which include inter alia strengthening research governance and management, science and mathematics education, and graduate training at doctoral degree level. On the private sector side, industries also need to be brought on board as more active partners, while governments need to take responsibility for architecting a national innovation system with appropriate frameworks and policies to govern and incentivize university-industry interactions* (Ssebuwufu and Teralynn, 2011)

Kamoun (2011) strongly argued that education and research institutions and the production sector constitute two critical components of the national innovation system. Building linkages between them should thus be closely cultivated and nurtured rather than left to chance or to the whims of a few researchers.

Furthermore, there must be no break in continuity between academic teaching and the teaching of technology or between higher education and the productive sector. Such an approach to differentiation does not lead to a fragmentation of teaching institutions but on the contrary, to greater complementarities between them. Moreover, the opening up of higher education to the needs of the labor market must be reflected in relevant teaching and research.

In other words, STI development demands greater innovation at every level of production, from knowledge production to economic production. This greater relevance must necessarily be reflected in a reinforcement of lifelong learning. Just as researchers must focus their research on what the market needs, technicians must be able to master the skills necessary to adapt the results of research and to convert them into practices and processes capable of influencing all actors in the productive processes.

4.8 TRANSFER OF TECHNOLOGY

A simple definition of transfer of technology (TT) is the "transfer of the results of academic research with the aim of marketing new products and services." It is therefore possible to refer to technology transfer as the objective of any program to reform the structures of higher education in order to make it the main driver for sustainable development. The expression "lifelong acquisition of scientific and technical skills for the sustainable development of Africa in the context of globalisation" covers the concept of technology transfer as an approach that makes scientific research a genuine contribution to palpable technological progress that can be converted into real innovation in every domain linked to development. In the African context, technology transfer has often been seen as an impediment to the introduction of national systems for innovation and technology and has been equated with technology imported from developed countries. In this sense, technology transfer means African dependence on technology-producing countries. Technology transfer is generally seen as a one-way process whereby the developing world gains access to products or expertise produced and owned by the developed world. However, there is nothing to stop Africa producing its own research and transforming it into an engine for development by turning it more towards technological production.

For transfer to be complete it is not enough for it to occur at the level of knowledge; it must also include the transfer of expertise. The development of the non-formal and informal sectors of education and the promotion of the lifelong acquisition of scientific and technical skills are necessary to the success of a TT plan. An example of this is the introduction of technology transfer in the agricultural sector, which involves transfer to a population group that is often a stranger to technological and scientific sectors. "The low productivity in the agricultural sector is due to low levels of adoption of technologies and their ineffective application, essentially because of insufficient mastery. These problems are directly linked to ineffective and inefficient mechanisms of technology transfer rather than the total absence of appropriate technologies. This situation makes it necessary to identify, explore, understand and control the interaction between a proposed technology and the physical, economic and social environment in which it will be used." (Young, 2007)

Given the high cost of TT in specific areas of science, African countries with limited resources wishing to introduce a technology transfer system can opt for the creation of a consortium of institutions in which the member countries share a central office (TTCO).

South Africa's experience offers an example of the way in which political will can guide scientific research towards the creation of a TT system. The government introduced a new strategy for R&D to build robust links between its emerging system for technology transfer and its research system. This led to the building of a new culture of innovation in every research community, and has ensured that all the benefits of research—including those that are social rather than commercial—are understood and used. The Southern African Research and Innovation Management Association was set up with the aim of being at the cutting edge of the national research and innovation capacity-building effort (Wolson, 2007).

4.9 EXPECTED ACTION POINTS

- Increase strategic investments in higher education by governments in partnership with the private sector in science and technology. Incentives and funding should target students and institutions moving into strategic fields in socio-economic development.
- Revitalize universities' research functions and capacities, maintain reliable management information systems (MIS), and institute collaborative platforms to promote innovations and entrepreneurship.
- Build collaborative partnerships with industry/ economic productive sectors to build and strengthen capacity to utilize STI for sustainable development.
- Establish interdisciplinary research and training COEs within and outside universities with emphasis on S&T and articulate benchmarks to be achieved.
- Increase support for post-graduate training programs and postdoctoral fellows in S&T.
- Build capacities of universities and other tertiary institutions to raise, manage, and utilize research funds. This would bring into the research and development process efficiency, accountability, and effectiveness in utilization of the resources available for research and innovation.
- Adopt a lifelong learning strategy focused on critical thinking, problem solving, communication, creativity, and responsible citizenship as well as acquisition of relevant knowledge and skills.
- Increased funding of Research and Development (R&D).

4.10 WAY FORWARD

The requirements for accelerated socio-economic development in Africa bring into focus multiple challenges facing tertiary education. Firstly, the traditional concept of university inherited at independence must be interrogated and expanded to include new ideas and the increasing numbers of secondary school leavers accessing higher education. Serious reforms are required at the tertiary level in the context of limited resources and the challenges of the rising unemployment among university graduates. Secondly, the style and structures of governance and management of tertiary institutions must change to bring in accountability, effectiveness, and efficiency in the utilization of available resources. Thirdly, learning and teaching processes and the courses offered must be reorganized to give priority to the acquisition of scientific and technological knowledge and skills for innovation and value addition to African natural resources. Fourthly, increased and diversified resources for tertiary education and training are needed. Hence, strong public-private partnerships (PPPs) need to be forged to improve the quality and relevance of programs offered and research undertakings. Dynamic partnerships to link universities to productive sectors are critical in bringing the products of research to the service of society.

A fifth challenge is that the initial training of teaching and research staff should be treated as a priority, to be complemented thereafter by continuing education to re-engineer, retool, and sharpen their capacities to meet the rapidly changing needs in research, knowledge, and skills. In addition, professionals working in the industry need to be given periodic opportunities to teach at universities, while lecturers should take time to familiarize themselves with work in the relevant industry to acquire practical experience and update their knowledge. This could create a healthy exchange of knowledge between the two sectors. Finally, student orientation and learning habits also need to change so that students can acquire critical skills and abilities to continue learning even beyond their tenure in tertiary institutions. These initiatives and programs should however be fully anchored in credible mechanisms for quality assurance, evaluation, and assessment. ■

05

EXCLUSION AND INEQUALITIES IN ACCESS TO SCIENCE AND TECHNOLOGY

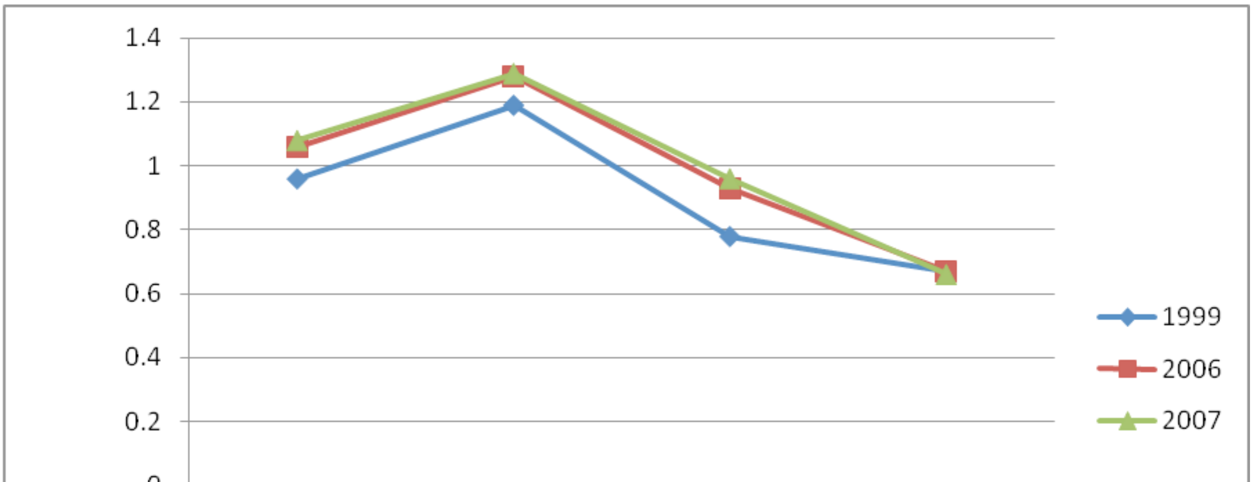
The inequalities in access to education that are subsequently manifested in S&T-related fields tend to fall into three broad categories: gender, regional, and socio-economic status. These inequalities are intertwined and tend to reinforce each other. This paper gives more attention to gender inequalities given that other forms of exclusion require better and systematic data which are not available. It should be noted that other forms of inequality have not received the same systematic and intense policy and research attention. Nevertheless, anecdotal evidence seems to suggest that these forms of exclusion are becoming entrenched, especially in the higher echelons of the education system. It is likely that these forms of inequality are manifested in the way employment opportunities and incomes are distributed in society.

Studies by the Forum for African Women Educationalists (FAWE) entitled *Strengthening Gender Research to Improve Girls' and Women's Education in Africa* and *FAWE Gender in Higher Education Research Synthesis for the ADEA Triennale* formed key contributions to the Triennale debates on the issues of gender and access to scientific and technological opportunities. In addition to gender-focused analysis, the studies provided useful data for our discourse.

5.1 GENDER INEQUALITIES

The past two decades have witnessed remarkable expansion of higher education opportunities in Africa as well as other regions of the world. Globally, the recent expansion of places in tertiary education benefited women (World Bank, 2011b). However, in Africa this

Figure 3: Gender parity index (F/M) in tertiary education, 1999, 2006, and 2007



	World	Developed Countries	Developing Countries	Sub-Saharan Africa
1999	0.96	1.19	0.78	0.67
2006	1.06	1.28	0.93	0.67
2007	1.08	1.29	0.96	0.66

Sources: UNESCO, 2009; 2010b.

has not been the case. The expansion has barely dented gender inequalities in most African countries, with the exception of four countries: Cape Verde, Mauritius, Namibia, and Tunisia. Enrollments in these countries have reversed gender trends, indicating more women are being enrolled at the tertiary level (AfDB *et al.*, 2011).

Figure 3 below shows global trends in gender parity for the period 1999 to 2007. The data indicate that while developed countries have achieved gender parity in tertiary education, developing countries still have some progress to make before reaching this benchmark. It is obvious that the expansion that has occurred and the interventions undertaken have not made great headway from a regional perspective. Nonetheless, differences between countries are discernible. It is in this overall context that gender inequalities in science and science-based professions should be analyzed and evaluated.
Below we shall summarize the existing and emerging patterns utilizing data and experiences gained from studies undertaken by FAWE in Ethiopia, Kenya, Lesotho, Nigeria, Senegal, and Zimbabwe. These will be supplemented by findings and insights from other studies and reports.

Since the inception of FAWE two decades ago as well as other advocacy initiatives, gender inequalities in education have received a great deal of attention in policy debates, research, and literature. It is not possible to summarize the intense and very rich debates that have taken place or the tremendous achievements made, but we would like to highlight the emerging patterns of gender inequalities in access to science and science-based courses in tertiary education institutions. The purpose is to indicate how these patterns influence access to scientific and technological careers and research.

Enrolment figures in Lesotho and Swaziland (Table 2) are largely similar, while those in Kenya and Zimbabwe have a pattern of their own. Women's university enrolments in Lesotho and Swaziland show a strong female presence in social sciences, education, and healthcare (above 50%). In Kenya and Zimbabwe, women's enrolment in these programs is below 50%, indicating continuing male dominance in these fields.

In the sciences in particular, women's enrolment is strong in Lesotho and Swaziland, with a third of enrolled students being female, while in Kenya and Zimbabwe the proportions are about a quarter, showing serious exclusion of women. In every program analyzed, women fared worse in Kenya and Zimbabwe than their counterparts in Lesotho and Swaziland.

Admission data for Kenyan universities in the past four years show the same pattern in terms of low enrolment in science-based professions such as medicine, education (science), computer science, and engineering.

The data provided above are to a large extent consistent with data from two higher education institutions in Kenya: Kenyatta University and Jomo Kenyatta University of Agriculture and Technology (FAWE, 2011).

The pattern to note in higher education enrolment is the low enrolment of women across the board in tertiary institutions in most African countries. This is

Table 2: Enrolments in various courses and programs of study by gender

Field of study	Country			
	Lesotho	Kenya*	Zimbabwe	Swaziland
	Female (%)	Female (%)	Female (%)	Female (%)
Social sciences	50.0	47.0	38.7	46.0
Education	68.0	47.7	46.7	55.0
Sciences	30.0	23.5	25.3	30.0
Agriculture	46.0	30.0	28.8	41.0
Health and welfare	94.0	41.2	n/a	51.0
Engineering	n/a	15.0	6.2	n/a

Sources: UNESCO, 2005; FAWE, 2011.
N/A: Data not available. *Data based on two institutions: Jomo Kenyatta University of Agriculture & Technology and Kenyatta University (FAWE).

a reproduction of the disparities at secondary school level and poor female transition rates from secondary to tertiary level (UNESCO, 2007b). Low enrolment in tertiary courses that require mathematics and sciences are a consequence of low enrolment and poor performance in these subjects at secondary school level. In this way, gender inequalities in tertiary education in many African countries have persisted despite an increase in the number of tertiary institutions and increased enrolments at this level. This is indicative of barriers women face in accessing the existing limited opportunities in tertiary education, and in particular courses and professions that require science and mathematics for admission.

This exclusion has a strong cultural dimension. It reflects prevailing patriarchal cultural attitudes that view science and technology as the preserve of men (Kenya National Council of Science and Technology, 2010). The entrenched perceptions act as a barrier to full participation of women in science, technology, and innovation. Indeed, women who qualify to join institutions of higher learning are not motivated to pursue courses in this field. Instead, they are often encouraged to undertake humanities and other subjects which do not prepare them for careers in scientific fields. Consequently, the proportion of women entering graduate schools and careers in science and technology in Africa remains marginal (Andres, 2011).

The solution is to improve girls' performance in mathematics and sciences at lower levels of the education system, and accelerate enrolments in higher education, particularly in science- and technology-related courses (ASSAF, 2011). Furthermore, there is an urgent need to incorporate gender sensitive policies in science and technology sectors. Such policies should incorporate affirmative action for women scientists such as equality in access to training in science and technology, scholarships, research grants, flexible work arrangements, and non-discrimination policies in the workplace (Kenya National Council of Science and Technology, 2010).

5.2 UNDERREPRESENTED AND UNDERUTILIZED POTENTIAL

The second observation that can be made is that women are underrepresented in fields related to scholarship, research, and development (UNESCO, 2010; Adams, King and Hook, 2010; AU-NEPAD, 2010; UNESCO-UIS, 2006; World Bank, 2011b). It is estimated that just 29% of African researchers are women. It is only in a few countries such as Cape Verde, Lesotho, Seychelles, South Africa, and Uganda that the proportion of women researchers is over 35% (UNESCO, 2010). In countries where women are limited in their career paths, they are also underrepresented in research and development disciplines. Consequently, women remain an underutilized resource in scientific and technological endeavors, including innovation, depriving Africa of the potential and talent of women (Dickson and Andres, 2011; Andres, 2011; ATPS, 2009). As indicated in Box 1, female youth experience a high rate of unemployment, meaning that they are underrepresented in the job market.

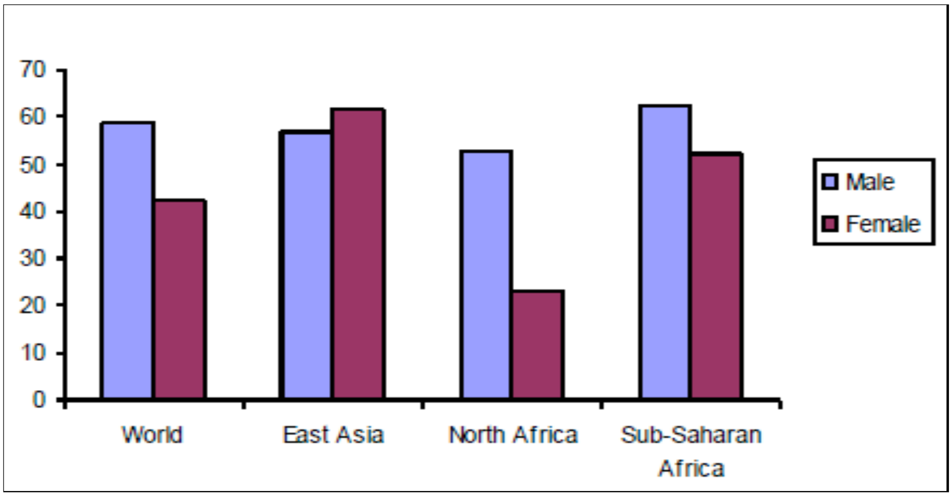
Box 1: Some indicators of female youth unemployment in Africa

As indicated above, the rate of unemployment among the youth is very high in Africa. However, the situation is more severe among female youth, particularly in North Africa. In Tunisia, for example, unemployment among women is high as 51% compared to 35% among males. Among female law graduates, unemployment is estimated at 68% (Tunisian Ministry of Employment and Professional Integration). In Egypt, unemployment rates among women are close to 50%, compared to less than 20% among men.

On average there are large disparities in female labor force participation within Africa. In West Africa, participation tends to be much higher than in the rest of the continent, averaging 80% and above in Burkina Faso, Burundi, The Gambia, Ghana, Guinea, and Sierra Leone. In East Africa, it is under 40% for Ethiopia, Kenya, Malawi, and Uganda (Kolev and Sirven, 2010). Most strikingly, the share of female participation in the labor force in North Africa is almost half that of Sub-Saharan Africa (Figure 4 on page 30). In addition, female youth in Africa may be at a greater disadvantage as they face family constraints. In Chad, Gabon, Malawi, Mozambique, Niger, and Uganda, 40-50% of women aged 15-24 years have already given birth at least once (World Bank, 2009a).

In sum, the future expansion of tertiary education must take cognizance of gender inequalities and focus on two critical issues: improving women's participation in higher education on the whole, and targeting access into science- and technology-related courses and programs as well as graduate schools. This targeting should incorporate other excluded groups and communities in each country.

Figure 4: Youth labor force participation rates by region and sex, 2010



Source: ILO, 2010.

5.3 OTHER FORMS OF EXCLUSION

While gender inequality in access to higher education has been a subject of many studies, policy debates, and comments, it should nevertheless be recognized that other forms of inequalities do exist at this level. The most obvious is the increasing marginalization of children from poor households in accessing tertiary education. In the first instance, children coming from conditions of poverty experience problems in accessing basic and secondary education, continuing to the next level of education, and performing well enough to be considered for the very competitive admission to tertiary education, and in particular to science-related courses and professions (PUIB, 2006).

Despite this situation, there is limited reliable data indicating current trends in terms of the chances of various social groups to access tertiary education opportunities, let alone science-related courses and professions. The chances of succeeding once enrolled are not known. In the absence of reliable data, it is recommended that empirical studies focusing on which students gain admission into tertiary education should be undertaken as a matter of routine to ascertain which social groups are being excluded or marginalized in higher education institutions.

5.4 EXPECTED ACTION POINTS

In general, it is evident that only all-inclusive and high quality science and mathematics education can create the critical mass of scientists and technologists needed to achieve African hopes of high economic growth, value-addition to its raw materials, innovation, and sustainable development (Ndoye, 2012).

Specifically, a stronger focus on education and training for women is needed, but this must be directed toward quality and relevance to the labor market. To make women competitive and confident labor market participants, choices of school subject studied and training/certification attained should be demand-driven rather than dictated by traditional job norms for females.

Furthermore, to improve the access and conditions of women in higher education it is important to increase resources for gender mainstreaming and implementation of national policies and to fulfill international commitments to EFA and the MDGs. Countries such as Kenya and Rwanda have formulated gender policies which mandate all public institutions to have at least a third of women in all institutions. Secondly, it is important to improve the socio-economic environment for girls and women to remain in school, undertake science related subjects, perform well, and thereafter succeed in tertiary education. Countries lagging behind should establish national gender observatories to spearhead capacity-building for women and to support institutions to mainstream and cater for participation of women in scientific and technological endeavors. Thirdly, harmful cultural norms such as early and forced marriages and discriminatory attitudes such as stereotyping must be changed through sustained social-cultural education and awareness.

Tertiary institutions can also improve the environment by consciously working towards gender parity in enrolment and by collaborating with gender stakeholders to initiate programs to mentor women who choose to enter the fields of science, technology, and innovation. A study conducted at the University of Dar es Salaam indicated some correlation between implementing and mainstreaming gender sensitive policies on one hand and, on the other, increased enrolment of women in science-based courses in the period between 2004 and 2010 (Masanja, 2010).

The gender inequalities observed in tertiary education and R&D can be traced to how science education is promoted in primary and secondary schools. Hence, teaching and learning of science by girls at the lowest levels of schooling are critical to their success later on. Since this is the real foundation for women's access and success in higher education and eventually their transition to scientific and technological careers, the teaching and practice of science at the lower levels of education should be enriched by mentoring and promoting change in attitudes among learners and teachers. The FAWE studies have underlined these aspects.

The attitudes of parents are also crucial in this respect. At the household level and in schools, the prevailing myth about girls' abilities in learning mathematics and science should be dispelled by well orchestrated public awareness and through the use of successful women scientists as role models. Whenever possible, scholarships and other incentives should be provided to encourage girls' and women's access to science-based professions and careers. While affirmative actions are required, it is the change in mindset among girls, parents, and women that can transform the current gender inequalities in education, and specifically mathematics- and science-related professions.

As indicated, one of the shortcomings of analysis of the emerging trends in girls' and women's access to mathematics- and science-based disciplines is lack of reliable and up-to-date data. It is therefore very important that countries and tertiary institutions maintain systematic and reliable data that is updated on a regular basis to enable policymakers, researchers, and other stakeholders to have dependable data for policymaking, interventions, and advocacy.

This concern about data is also key in analyzing other forms of social exclusion. Accordingly, institutions should be required to maintain comprehensive data on students' educational, family, and socio-economic background. This could be supplemented by quantitative and qualitative empirical research conducted on a regular basis. The data gathered could be utilized in the development of strategic interventions to ensure inclusion and equal access to science and technology education. ■

06

ICT FOR SCIENTIFIC AND TECHNOLOGICAL CAPABILITIES AND INNOVATIONS

In the past two decades, African countries have experienced dramatic growth in the use of ICT, and especially Internet and telephony (ITU, 2010; Grosskurth, 2010; UNECA/IST, 2010; UNESCO, 2010). Africa's Internet access has increased by a factor of 20 in the past five years, supported by over 68,000 kilometers of submarine cable and 615,000 kilometers of national backbone networks (Business Daily, 2012). The use of mobile subscriptions grew from 25 million in 2001 to about 650 million in 2012. Two thirds of African adults have access to ICT, especially mobile phones, with countries such as Kenya enjoying the highest levels of connectivity of above 70% of the population (Yonazi *et al.*, 2012). Significantly, the expansion in the use of mobile phones has led to the growth of a vibrant mobile applications development sector which has delivered applications targeting critical development issues. Applications in mobile money transfers (M-Pesa, Kenya), agricultural market information services (Esoko, Ghana), pre-paid transport cards (Beba pay, Kenya), disaster response (Ushahidi, Kenya), authentication of medicine (mPedigree), market for agricultural products (M-Farm, Kenya), health (MeDafrica, Kenya and Etisalat mobile baby, Tanzania), social networking (MXit, South Africa) and others have been developed. Moreover, the expansion in ICT use has added 7% GDP growth in Africa (Yonazi *et al.*, 2012).

The power and benefits that accrue to the adoption and utilization of information and communication technologies in education, lifelong learning, trade and commerce, and participation in the global economy competitively cannot be gainsaid. The current growth of the ICT sector in Africa remains a critical asset with long-term positive gains across the political, social, and economic spheres. Nowhere is this more pronounced than in the financial services sector. In Kenya, where ICT has played a pioneering role in mobile money transfers, the amount of money transferred in 2012 stood at 1.117 trillion Kenya shillings, amounting to a third of the country's GDP (World Bank, 2010). A 2010 World Bank report notes that due to this development, the country has managed to grow financial inclusion from 5% in 2006 to above 70% in 2012.

To support and tap into the rising demand and continue to broaden ICT accessibility and utilization on a large scale on the continent, organizations and institutions have taken advantage of opportunities arising from regional cooperation to establish networks across Africa. Ordinary people, too, have embraced ICT in their social interactions, learning, and business. A case in point is the ICT-based innovation for money transfer using the mobile phone platform called M-Pesa which has been adopted in Kenya with great success (see Box 2).

6.1 CHALLENGES OF ICT IN AFRICA

Despite the encouraging growth of ICT in Africa, numerous challenges have hampered full utilization of ICT applications and maximization of the opportunities available. Key challenges include: articulation of ICT policies and strategies; development of ICT infrastructure; and capacity-building.

6.1.1 Articulation of ICT policies

Many African governments have developed economic blueprints that have identified science and technology as a platform for economic and societal transformation and recognize ICT as a catalyst for change. Existing development plans and vision documents have underlined the observation that the future of African socio-economic development will largely depend on embracing the use of ICT in a wide range of activities, such as education, agriculture, financial services, and health care. Consequently, many governments have formulated and adopted national ICT policies while others are in the process of establishing ICT parks (AU/NEPAD, 2007; UNESCO, 2010; Kenya Vision 2030).

However, the opportunities that come with articulation of policies and adoption of national ICT strategies in Africa will not be realized unless implementation becomes a priority and adequate funding by governments in partnership with the private sector is

Box 2: M-Pesa: Mobile money transfer service

M-Pesa is an ICT-based innovation which enables the transfer of money using a mobile phone. It involves registered mobile phone subscribers, the mobile operator and mobile phone outlets or agents in various business locations, including in rural areas. This service enables any customer anywhere in Kenya to transact business in the country regardless of the status of transport and banking infrastructure in their locality.

The service revolves around users depositing money with the mobile operator through outlets or agents and the operator facilitating money transactions to other users without the mediation of financial institutions. This has eased financial transactions in a fundamental way. A customer simply needs a mobile phone, a working telephone network and an identification document to access the service.

The impact of this innovation in Kenya has been remarkable and it has proved very popular with ordinary people not well served by banks or financial services. Bank customers save time by not making trips to banks to transfer funds.

Most banks and businesses in Kenya have entered into partnership with the M-Pesa service provider to anchor their money transfer services on the platform. The anchoring allows users to conduct transactions such as depositing and withdrawing money from retail agents, banks and other financial services providers. Customers are also able to use this service to pay for goods and services from institutions and enterprises that have subscribed to the platform.

M-Pesa was launched in Kenya by the dominant mobile phone operator Safaricom in March 2007. The service has an estimated 16 million customers and over 40,000 agents countrywide and transacts on average 2 billion Kenya shillings daily. Since its inception in 2007, the service has had exponential growth, bringing convenience and ease of money transfer to millions of people. It is a widely used money transfer service in Kenya, Tanzania, South Africa and Afghanistan, among other countries.

Over time the service has evolved to incorporate a savings concept called M-shwari. This is an interest earning mobile account where customers can save and access emergency loans of 100 to 20,000 Kenya shillings payable within a month at 7.5% interest. The service spares customers the often long process of accessing loans from banks since there is no paperwork involved and the entire transaction takes just a few minutes. Although the interest charged is high—it translates to a 90% per year flat rate, with a more than 80% loan repayment rate—the service has become popular among Kenyans. Just three months since its inception in December 2012, more than 378 million Kenya shillings had been disbursed as loans while customer deposits had grown to 3 billion Kenya shillings.

The success of M-Pesa is well documented and has spurred other innovations such as Ushahidi. It has also fired the imagination of Kenyan youth to search for similar innovations to serve other sectors such as agriculture, education, and health. This enthusiasm is evident in the mushrooming of I-hubs in Nairobi.

Sources: Gidoomal, 2011; Oanda, 2013; Namata, 2012; Okuttah, 2012; Safaricom, 2010 and 2013; Omwansa, 2009.

secured. National governments have shown leadership in the development of the required infrastructure, legal regulatory frameworks, transparency, and accountability in the allocation of opportunities and in building capacities (Farrell and Shafika, 2007).

The critical need now is to create an enabling environment for public-private partnerships which will enable the expansion of ICT infrastructure and access throughout each country. African countries should then articulate policies to safeguard the intellectual property rights of local innovators in this field. Where policies are in place, awareness should be ensured and mechanisms for their enforcement strengthened to spur development of a fully fledged ICT sector.

The integration of youth into ICT policies and programs need to be expounded clearly and measures taken to implement them in order to avoid continued marginalization. Youth policies must embrace measures that tap into their enormous energies and ingenuity to create innovations that will contribute to the development of African economies.

6.1.2 Strengthening ICT infrastructure

ICT infrastructure is a major factor in accelerating development in the 21st century. In the past, Africa lagged behind because it neglected modernizing its technologies. There is still a major digital divide between Africa and the rest of the world that could continue to widen if Africa does not invest heavily in ICT infrastructure to tap into the existing potential for development (UNESCO, 2010). Nevertheless, remarkable progress has been achieved in the recent past with most states now connected via high speed undersea and terrestrial fiber optic cable networks and a host of wireless voice and data transmission devices. The main issue now is how to enhance last mile access especially in rural areas and promote productive use of the ICT infrastructure in education, agriculture, health, and other activities critical to the realization of sustainable development and global competitiveness. Importantly, individuals need to be empowered through awareness, education, and training so that they are able to integrate ICT in their daily lives.

6.1.3 Enhancing ICT capacity

Having quality capacity as well as quantity, particularly in ICT, is critical to building a creative and innovative knowledge society for sustainable socio-economic development. Building scientific capacity requires not only adequate funding and infrastructure but also effective linkages where information and experiences are shared and learned. National governments that have embraced ICT in their economic development plans and vision documents need ICT professionals to oversee implementation of the agreed policies and plans (UNESCO, 2010).

The shortage of professionals is real, and those in place overworked and underpaid. The few trained and skilled professionals tend to seek alternatives elsewhere to improve their incomes and professional careers (Hooker, 2010). This leads to brain drain in a field where shortages are likely to slow the much expected accelerated development. Manoj Shanker, CEO of Techno Brain, a major player in ICT in East Africa, when asked about the key challenge in doing business in Africa, answered:

> *We face many challenges and a major one is finding highly skilled individuals. Our focus is to continuously develop in-house capacity to produce world-class programmers, consultants, project managers, R&D engineers and others. There are many hidden talents in Africa and what they need is training, industry exposure, certifications and relevant assignments to bring them in line with the rest of the world. We have decided to open a research and development software centre in Nairobi this year which will be the first of its kind in East Africa. The centre is expected to employ 100 plus consultants during the first year.*
>
> *I strongly believe that in the next 20-30 years Africa will be a force to reckon with in the area of technology and it will also become a great source of manpower to the world. Governments must look beyond building infrastructure and start investing in building local content. I believe Africans can provide the best solutions to African problems. There is no dearth of talent here.*
> (*The East African*, January 2-8, 2012)

Where capacity is weak or limited, ICT cannot be fully embraced and enhanced in all sectors of the economy. The youth bulge in Africa provides a unique opportunity for training and building the capacities of the next generation of professionals and innovators.

6.1.4 ICT and Africa's cultural systems

NEPAD has stressed the need to develop software whose content is close to Africa's cultural systems. The present need is for ICT development to be well coordinated and organized at regional level under a plan for cooperation between the centers of excellence in the various countries. One domain which could intensify Africa's ICT revolution and which could benefit higher education is innovation, development, and maintenance of free and open-source software (FOSS). FOSS enables access to users in countries whose resources are fairly limited, as is the case for those in Africa. FOSS projects can encourage collaboration and intensive resource use. In addition, the various types of software developed would have common features and for this reason, it would be possible for skills development in this area to lead to the development of critical capacities essential to the development of research. With this in mind, the aim for African countries must be to put in place cross-border networks for ICT development and projects that produce software with African content. There is also a need to guide this effort in the direction of two specific domains: the production of e-learning software and the development of e-learning capacities.

6.2 EXPECTED ACTION POINTS

- National governments should give priority to the improvement of ICT infrastructure by increasing bandwidth and connectivity and at the same time paying attention to affordability, reliability, and penetration. This will create an enabling environment for the acquisition and utilization of scientific and technological knowledge, skills, and competence by policy makers, students, youth, teachers, researchers, innovators, and techno-entrepreneurs. For these broad objectives to be realized, partnerships between stakeholders are required—the public sector, the private sector, civil society, and development partners.

- Most ICT infrastructure is concentrated in urban areas, particularly in the cities, leading to regional disparities. To reduce these disparities, national governments, with support from and in collaboration with stakeholders, should invest increased resources to improve ICT infrastructure in rural and remote areas in order to promote digital inclusion.

- To increase ICT literacy and enhance Internet accessibility among learners and teachers, national governments and ministries of education should incorporate ICT learning in school curricula as one of the common core skills. Ownership and access to computers and Internet by institutions and individuals are critical elements to the realization of this goal. Africa can learn a great deal from the South Korean experience in this respect.

- To cultivate a culture of innovation and entrepreneurship among the youth, there is need to strengthen and expand ICT hubs and centers as platforms where young people can explore new ideas. These centers should not only expose young people to new technologies, but also nurture their entrepreneurial skills and creativity. Public and private sector partnership is critical to the success of such hubs.

- Many inventions and innovations within Africa are either underreported or pirated due to lack of clear guidelines on how to apply for patent rights. Clearly articulated guidelines on issues related to patent rights will help young African innovators to effectively participate in and benefit from national science, technology, and innovations systems. African governments, with the support of global agencies such as the World Intellectual Property Organization (WIPO), should ensure the intellectual property rights of local innovators are safeguarded.

6.3 WAY FORWARD

Countries in Africa should go beyond articulating policies and investing in ICT infrastructure to building a critical mass of professionals to spearhead the changes required to realize the MDGs and sustainable development in the context of emerging technologies and innovations.

They should also promote ICT not just a means of facilitating research, teaching, and development but also as a fully fledged sector of the knowledge economy, whose development is integral to economic development itself. This approach has been proved by some Asian countries, such as India, which has managed to develop a globally competitive software development industry. All these reforms require a long-term strategy culminating in the creation of technology development systems through which Africa will cease to be simply a recipient and consumer of technology produced by others. ■

07

GALVANIZING PUBLIC SUPPORT FOR SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT

7.1 POLITICAL LEADERSHIP AND OWNERSHIP OF STI

Strong political will is needed in each country in order to enable adoption of appropriate policies and programs, creation of institutions, building of capacities and provision of resources for R&D, adoption of innovations, and their dissemination into the productive sectors of the economy. Hence, scientific and technological agendas for research and innovation need to have concrete support from and ownership by a broad spectrum of stakeholders—politicians, policymakers, the scientific community and professionals, civil society, the private sector, and the general public.

Public ownership of policies and programs can be fostered and garnered through the processes employed in articulating national visions and strategic plans. Participation and engagement of the public and interested stakeholders in the ensuing debates is paramount. Also, inclusiveness in the crafting of national policies is critical in building a sense of ownership and appreciation of the benefits expected from adopting appropriate scientific and technological policies, institutions, and strategies.

Political leadership is also required in mobilizing the public and other stakeholders to support national agendas for science and technology. Such support is necessary in the allocation of resources and elaboration of strategies for the integration of regional and international commitments into national visions and plans. Collective action is also needed in the implementation, monitoring, and evaluation of national agendas for science and technology.

7.2 BUILDING PUBLIC AWARENESS

A recent study entitled *Use of Scientific and Technological Evidence within the Parliament of Uganda* carried by the UK Parliamentary Office of Science and Technology, the Parliament of Uganda, and the Ugandan National Academy of Science, focused on Ugandan parliamentarians' knowledge and awareness of issues pertaining to the development of science and technology in Uganda (Chandrika, 2011). The study's findings indicate serious S&T knowledge gaps among a critical segment of policymakers. According to these findings, politicians are not well versed in the intricate and complex factors that need to be taken into consideration when formulating science and technology policies. The study underscored the need for building awareness among parliamentarians, policymakers and other players responsible for the formulation and implementation of national science and technology agendas (Chandrika, 2011).

Since science, technology and innovation are critical to the realization of the MDGs and the harnessing of national resources for socio-economic development, it is important that public awareness among all stakeholders is provided for. Various mechanisms—teach-ins, seminars, conferences, workshops, etc.—could be organized for this purpose. This way, existing gaps in knowledge and support between political intentions and the needs of research communities and other players could be minimized. This could also pave the way for better utilization of existing capacities, resources, and infrastructures.

Enhanced dialogue between policymakers, scientists, technologists, and other stakeholders is therefore needed. Space should be accorded in particular to the private sector, local communities, and civil society to express their views, indicate priority areas, and signal what would constitute the responsibilities of each stakeholder in realizing the goals of national projects for STI. Essentially, science and technology efforts need to be democratized. In addition, Africa needs to be aware of and unburden itself from its painful history in order to overcome various psychological, sociological, cultural, and ideological barriers that prevent the continent and Africans seeing the present and future with clarity (Ndoye, 2012).

7.3 THE ROLE OF MEDIA IN SCIENCE AND TECHNOLOGY

The critical role of print and electronic media in educating the public and other stakeholders on what is entailed in scientific and technological policies and programs must be recognized. These channels can be utilized to educate the public on how the adoption and implementation of STI policies and strategies would impact on poverty alleviation, health care, quality of education, and employment creation, as well as enhance global competitiveness and overall sustainable development. Media as a paramount public agenda setter is therefore a critical partner in any country in advancing the scientific and technological agenda for socioeconomic development. It is vital that media institutions recognize and underscore this role, and utilize the available spaces and capacities for building public awareness. In addition, the media should engage various players on critical discourses on the development and utilization of scientific and technological capacities for development. We need to recognize and appreciate the contributions made by media players such as the Science and Development Network in this regard.

Additionally, media can bring issues of acquisition, adoption, and utilization of scientific and technological knowledge and skills in socio-economic development constantly into the foreground for debate, assessment, evaluation, and reform. Such sustained focus, together with the demonstrated positive impacts of science and technology, when brought to public attention can be influential, eventually leading to positive changes in perceptions regarding science and technology. Furthermore, the targeted users of technology should be well educated on its use and supported to benefit from it (Karembu, 2002).

Hence, broad partnership and collaboration are required at the continental, regional, national, and institutional levels between politicians, policy makers, educators, funding agencies, knowledge producers, innovators and product developers and users in the various sectors. In this way, political support, resources, capacities, public and private sector goodwill, and awareness can be galvanized for development, thereby sustaining vibrant and productive scientific and technological communities in Africa.

7.4 EXPECTED ACTION POINTS

- The portrayal of science and technologic issues needs close study with a view to improving the image of S&T in the public domain.
- Creative engagement with the media with the goal of improving reporting and the portrayal of research, science and technology projects as well as dissemination and utilization of innovations in the productive sectors.
- Build awareness among all stakeholders on the usefulness of S&T in value-addition to natural resources, industrialization, employment creation, and sustainable development.
- Create a convergence between different actors in innovation, policymakers, and the public. This kind of consensus can facilitate consistency and continuity of policies and their implementation. The existence of such a consensus in national structures of governance is an important asset for all countries in order to succeed technologically.
- Create the necessary institutions for diffusing technologies and educating users on their sustainable and productive use. ■

08

STRENGTHENING REGIONAL COOPERATION AND INTERNATIONAL ENGAGEMENTS

Continental, regional, and national policy documents reviewed in this synthesis paper indicate full awareness of the benefits derived from regional cooperation. Regional structures have been created to accelerate market integration, improve trade and enhance the infrastructure needed for realizing the overall improvement of people's welfare. A number of institutions to advance scientific and technological research and capacity have also been established and are located in various regions. These are in addition to regional institutions established well before the AU/NEPAD initiatives were instituted. It is also noteworthy that countries have not only articulated their national strategies for scientific and technological development but also indicated possible areas for regional cooperation to harness regional potential, resources, and limited scientific and technologic capacity in each African country (AU/NEPAD, 2007; ATPS, 2010; Kamoun, 2011).

The provision of quality institutions for the development of science, technology, and innovation requires enormous resources—financial, infrastructural, and human—which can be pooled through regional initiatives. Advanced research all over the world is expensive, hence regional cooperation and international collaboration is needed to garner the much needed funds, maximize and rationalize scarce resources and capacities, and draw upon a wide range of experiences and expertise available beyond national boundaries. The regional approach to research stems from the recognition that some of Africa's problems go beyond national boundaries and are manifested across many countries and regions. Problems related to health, agricultural and livestock development, drought, and climate change are regional in character and require cooperative efforts to get solutions.

While AU/NEPAD, UN agencies and RECs have been at the forefront in articulating regional agendas for advancement of scientific and technological research and capacity, it is at the implementation stage that problems persist. Turning intentions into actions and programs remains the main obstacle to pursuing the policies and programs that African countries have collectively committed to undertake. Issues such as lack of systematic funding of regional entities and nationalism have often hampered regional integration and cooperation efforts.

The idea of regional cooperation and collaboration is not new. It has been embraced by African countries since independence and the establishment of the Organization of Africa Unity (OAU). In the domain of S&T, the Lagos Plan of Action remains a pioneering document which recognized science and technology as critical for Africa's development and self-reliance. It was accepted as a basis for cooperation and collaboration among African countries and institutions. The AU/NEPAD CPA has followed this visionary thrust closely. The enduring question is whether this agenda will receive the necessary political will and financial backing to succeed.

8.1 BUILDING ON THE STRENGTH OF REGIONAL INSTITUTIONS

Africa has a number of excellent regional science and technology institutions and networks spread all over the continent. The challenge is building on this regional architecture of institutions and experiences. While national governments shoulder the responsibility of hosting these institutions, they recruit their staff internationally, thereby attracting talent wherever they can find it. Funding is also international. Whereas the international profile of these institutions is usually high, their interaction with national research communities and institutions is not always fine-tuned (PUIB, 2006). This is a challenge given the need for local communities to see the benefits of research and innovation emanating from these institutions.

Moreover, though intentions and regional cooperation agreements are well articulated, implementation is a continuing challenge at both national and regional levels. Even where African countries have well developed scientific capacities and national research systems, (e.g., Egypt, Kenya, Nigeria, Morocco, Tunisia, and South Africa), implementation of continental agreements is problematic. For instance, most countries have found it difficult to allocate the agreed 1% of their GDP to research and development. For the present, only South Africa has done so.

Nonetheless, it is necessary to appreciate that African countries have worked closely within the framework of international bodies to develop their national scientific and technological capacities. For instance, UNESCO, the World Bank, and UNECA have individually and collectively been a positive influence on development of ideas and programs related to the advancement of science and technology in Africa (AU/NEPAD, 2007; UNESCO, 2010).

Bilateral agencies have also contributed greatly to the development of science and technology institutions and capacities in Africa through agencies such as the Japan International Cooperation Agency (JICA), the International Development Research Centre (IDRC), DAAD, the Swedish International Cooperation Development Agency (SIDA), the Department for International Development (DFID), and the United States Agency for International Development (USAID).

In addition, private foundations have provided funding for training, research, and infrastructure development in the region. The contributions of private philanthropy represented by foundations such as the Ford, Rockefeller, and Bill and Melinda Gates Foundations are well known in critical fields such as agriculture, water, health, micro-finance, higher education, and ICT.

These and other likeminded agencies have supported national and regional research institutions to develop and utilize science and technology capabilities to address Africa's socio-economic and environmental concerns. Some have been critical in helping to retain and attract talent to Africa (Mugabe, 2009; Barugahara and Tostensen, 2009; Banji, 2005).

8.2 UTILIZING THE AFRICAN DIASPORA

The African Diaspora has become a force to reckon with, particularly because of the enormous resources coming to the continent through their remittances. Tapping the trained and qualified human resource base in the Diaspora to support the development of science and technology in Africa is a big challenge and also an opportunity. How this can be done formed part of the discussions held during the Diaspora Day organized as part of the 2012 ADEA Triennale. It emerged from these discussions that the starting point is to create mechanisms for dialogue with the aim of tapping into the enormous potential represented by the African Diaspora. While ADEA has already begun this a process, these initiatives must go hand in hand with targeted policies and programs in order to stem brain drain.

8.3 EXPECTED ACTION POINTS

- Political support, which remains critical not only in the articulation of policies and programs but also in pushing for implementation of the agreed regional agenda, targets and timelines. This should be coupled with mechanisms for evaluation and monitoring of desired outcomes.
- Building on the experiences of African institutions and networks. There are useful experiences from both sciences and social sciences, for example from ILRI, ICIPE, ATPS, the Consortium for Advanced Research Training in Africa (CARTA), the African Economic Research Consortium (AERC), the University, Science, Humanities and Engineering Partnership in Africa (USHEPiA), and Africa Institute of Mathematic and Science (AIMS), among others.
- Turning good intentions into strong programs, institutions, and capacity for implementation by setting up regional and national targets, strategies, and follow-up mechanisms. The key is to strengthen implementation strategies at national levels to realize both local and regional agendas.
- Increasing funding for regional institutions and strengthening capacity-building efforts through postgraduate programs and postdoctoral fellowships, while at the same time providing incentives to attract qualified labor regionally and from the Diaspora. In addition, strengthening staff exchange in Africa to maximize on STI capacity and intensifying south-south exchanges and mutual learning.
- Building on existing cooperation and collaborative initiatives and programs among African universities, especially in carrying out research on common regional problems such as health, water, agriculture, and climate change. Lessons learnt from establishing the African University of Science and Technology (AUST) and the Pan African University should shape future initiatives.
- Enhancing cooperation and collaboration among RECs, African universities, regulatory bodies, and networks on issues of quality control and assurance, harmonization of degree programs, graduate studies, and exchange of staff and students.
- An assessment of regional skills needed to enable rationalization and maximization of scarce resources, cooperation, and targeting of the sectors identified as strategic.
- Rigorous implementation of up-to-date policies to stem brain drain, especially in strategic sectors.

8.4 WAY FORWARD

Problems of marginalization in science and technology, globalization, and sustainable development, cut across all African countries. At the same time, opportunities for turning the vast natural resources in Africa into a platform for economic growth, industrialization, and employment creation are spread over the entire continent. In order to change the current situation and utilize the existing opportunities, Africa requires solid and consistent regional and international cooperative and collaborative strategies for STI.

Regional cooperation in tackling this challenge makes great social, economic, financial, and intellectual sense. Hence, a close partnership of national governments, regional entities and networks, international organizations, the private sector, and civil society institutions is critical to unraveling African potential. ■

CONCLUSION

Africa has many assets to build on: its youth, which is becoming increasingly educated; its vast natural resources; the diversity of its tropical lands; and its cultural and spiritual optimism. At the same time, it faces seemingly indomitable challenges of poverty, health (HIV/AIDS, malaria, TB, and emerging lifestyle diseases), unemployment, food security, climate change, energy, conflicts and wars, and overall sustainable development.

The continent needs to turn its assets into opportunities to deal with the very serious problems it faces. The acquisition and utilization of scientific and technological capacity is crucial to this endeavor. Hassan (2009) argued that, *"Africa does not have scientific, technological or innovative capacity to effectively address the challenges it confronts"*. This paper affirms, however, that the situation is rapidly changing and makes bold suggestions on critical actions needed for fundamental transformation of the current reality. The existing situation is not permanent; recent developments have shown this. Africa can turn its resources into opportunities for vibrant and sustainable socio-economic growth (The Economist, 2013).

In essence, this entails going beyond the articulation of appropriate policies and programs at continental and national levels to the implementation of far-reaching reforms and the creation of requisite capacities at national and institutional levels. This document also recognizes a number of areas where changes are required. They include: teaching and learning of mathematics and sciences at all levels of the education system, building scientific and technological capacity among the youth, revitalizing research and innovative capacities of universities and linking them to productive sectors of the economy, ensuring the inclusion of girls and women and marginalized groups in the development of scientific and technological capacity, fostering regional cooperation and building of public awareness; and funding for STI. Additionally, building and strengthening ICT infrastructure and capacity as a platform for change and innovation is an integral part of this process. In addition, this paper emphasizes the need for lifelong learning and strong strategies for implementing the changes needed. These were some of the key messages emerging from the intense discussions held in Ouagadougou, Burkina Faso, during the 2012 ADEA Triennale.

There is a rising optimism in Africa, buoyed by recent high rates of economic growth, discovery of more natural resources, democratic and governance reforms, rapid adoption of ICT, increasing local and foreign investments, the impact of Diaspora remittances, and the rising levels of educational attainment and aspirations of African youth (The Economist, 2011; McKinsey, 2010; AfDB, 2011; Africa Commission, 2009; Miguel, 2011). To transform this optimism into real gains, Africa must treat science and technology as critical tools for wealth and employment creation (Kaberuka, 2012). Africa needs to recognize that it is not a matter of running, but running much faster to catch up on socio-economic development. In short, it has to win the global marathon of sustainable development. ■

REFERENCES

Academy of Science of South Africa (ASSAF). 2011. *Inquiry-Based Science Education: Increasing Participation of Girls in Science in sub-Saharan Africa. Policy-makers' Booklet*. Pretoria: ASSAF.

Adams, Jonathan, Christopher King, and Daniel Hook. 2010. *Global Research Report Africa*. Leeds: Thomson Reuters.

ADEA. 2011. *Report on the Youth Consultation Forum, October 19-21, 2011, Rabat, Morocco*. ADEA Triennale 2012 working document.

Adedeji, Adebayo. 1985. "The Monrovia Strategy and the Lagos Plan of Action: Five Years After". In *Economic Crisis in Africa: Perspectives on Development Problems and Potentials*, eds. A. Adedeji, and T. Shaw. Boulder, Colorado: Lynne Rienner Publishers.

AfDB, ECA and AU. 2008. *Achieving Gender Equality and Women's Empowerment in Africa. Progress report.* 6th African Development Forum (ADF VI), November 19-21, 2008. Addis Ababa: ECA.

AfDB, ECA, UNDP and AU. 2011. *Assessing Progress in Africa toward the Millennium Development Goals. MDG Report 2011*. Addis Ababa and New York: ECA, AUC, AfDB, UNDP.

AfDB. 2008. *Strategy for Higher Education, Science and Technology*. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents (May 4, 2013).

AfDB. 2011. *Africa in 50 years' Time: The Road towards Inclusive Growth*. Tunis: AfDB.

Africa Commission. 2009. *Realizing the Potential of Africa's Youth*. Copenhagen: Ministry of Foreign Affairs of Denmark.

African Technology Policy Studies Network (ATPS). 2009. *Young Professionals and Women in Science Competitions: Improving Agricultural Performance in Sub-Saharan Africa*. Technical report of the CTA/ATPS/AGRA/FARA/NEPAD/RUFORUM.

Allafrica.com. 2012."Africa: Improved Access to ICT can boost the Continent." *AllAfrica.com* June 6, 2012. http://allafrica.com/stories/201206060457.html. (May 4, 2013).

Altbach, Philip G., and Jamil Salmmi, eds. 2011. *The Road to Academic Excellence: The Making of World Class Research Universities*. Washington, DC: World Bank.

Andres, Jeanne Therese H. 2011. *Overcoming gender barriers in science: Facts and figure*. http://www.scidev.net/en/feature/overcoming-gender-barries-in-science-facts-and-figures-1.html (December 14, 2011).

AU. 2007. *Strategy to Revitalize Technical and Vocational Education and Training (TVET) in Africa*. Addis Ababa: African Union.

AU-NEPAD. 2007. *Africa's Science and Technology Consolidated Plan of Action*. Pretoria: AU-NEPAD.

AU-NEPAD. 2010. *African Innovation Outlook 2010*. Pretoria: AU-NEPAD.

Barugahara, N. I., and A. Tostensen. 2009. *Science and Technology for Development: The Institutional Landscape in Africa and Europe*. CAAST-Net.

Brok, Derek. 2003. *Universities in the Marketplace: The Commercialization of Higher Education*. Princeton, New Jersey: Princeton University Press.

Chataway, Joanna, James Smith, and David Wield. 2005."Partnerships for Building Science and Technology Capacity in Africa: Canadian and UK Experience." Paper prepared for The Africa-Canada-UK Exploration: Building Science and Technology Capacity with African Partners, London, UK, January 30-February 1, 2005.

Chinguta, Francis. 2002."The Socio-Economic Situation of Youth in Africa: Problems, Prospects and Options." Paper presented at the Alexandria Youth Employment Summit, Alexandria, Egypt, September 7-11, 2002.

Comaroff, Jean, and John L. Comaroff. 2005."Reflections on Youth from the Past to the Post Colony." In *Makers and Breakers: Children and Youth in Postcolonial Africa*, eds. Alcinda Honwana and Filip De Boeck. Oxford: James Currey.

Diarra, Mohamed Chérif. 2011. *Invest in Science and Technology or Perish: The Challenges faced by Faculties of Science and Technique, Schools of Engineering & Polytechnics at the age of the Knowledge Economy. Cases studies from Nigeria and Senegal*. Unpublished.

Dickson, David, and Jeanne Therese H. Andres. 2011."Women in science: still an untapped resource." http://www.scidev.net/en/editorials/women-in-science-still-an-untapped-resource-1.html (June 28, 2011).

Diouf, M. 2003."Engaging Postcolonial Culture: African Youth and Public Space." *African Studies Review* 46 (2): 1-12.

Durham, Deborah. 2004."Disappearing Youth: Youth as a Social Shifter in Botswana." *American Ethnologist* 31(4): 589-605.

Farrell, Glen and Shafika Isaacs. 2007. *Survey of ICT and Education in Africa: A Summary Report, Based on 53 Country Surveys*. Washington, DC: infoDev/World Bank.

FAWE. 2011. *Strengthening Gender Research to improve Girls' and Women's Education in Africa. FAWE Research Series Vol. 1-2010*. Nairobi: FAWE.

Gavin, Michelle. 2007. "Africa's Restless Youth." In *Current History*, May 2007: 220-226.

Gidoomal, Shalini. 2011. "Technology Innovation: Pioneering." *Msafiri* 77 (September-October 2011).

Gorjestani, Nicolas. 2000. "Indigenous Knowledge for Development: Opportunities and Challenges." World Bank.

Government of Kenya. 2007. *Kenya Vision 2030: A Globally Competitive and Prosperous Kenya*. Nairobi: Government Printer.

Grosskurth, Jasper. 2010. *Future Technologies of Africa*. Den Haag: STT.

Hassan, Mohammed H. A. 2009. "Promoting Science, Technology and Innovation for Sustainable Development." Executive summary prepared for First Session of the Committee on Development Information, Science and Technology (CODIST-1), ECA, Addis Ababa, Ethiopia, April 28-May 1, 2009.

Holbrook, Jack. 2009. "Meeting Challenges to Sustainable Development through Science and Technology." *Science Education International*, 20 (1/2), December.

Honwana, Alcinda and Boeck De Filip. 2005. *Makers and Breakers: Children and Youth in Postcolonial Africa*. Oxford: James Curry.

Hooker, Mary. 2010. *Concept Note: Building Leadership Capacity for ICT and Knowledge Societies in Africa*. GeSCI.

Hörig, Michael. 2011. *Offering relevant higher education qualifications in the context of globalization: Discussing the concept of the 'Centres of African Excellence'*. ADEA Triennale 2012 working document.

ILO. 2010. *Global Employment Trends for Youth: Special issue on the impact of the global economic crisis on youth*. Geneva: ILO.

International Telecommunication Union (ITU). 2010. *World Telecommunication/ICT Development Report 2010: Monitoring the WSIS Targets*. A mid-term review. Geneva: ITU.

Juma, Calestous, and Lee Yee-Chong. 2005. *Innovation: applying knowledge in development*. UN Millennium Project Task Force on Science, Technology, and Innovation. UK and USA: Earthscan.

Kaberuka, D. 2012. "Africa Ministers Commit to Strengthening Science and Technology in Africa to Boost Employment and Growth." Paper presented at the First African Conference on Science, Technology and Innovations for Youth Employment, Human Capital Development and Inclusive Growth, Nairobi, Kenya, April 1-3, 2012.

Kamoun, Farouk. 2011. "Is Innovation the Key to Industrial Development in Africa?" Paper prepared for the Second Session of the Committee on Development Information, Science and Technology (CODIST-II), Addis Ababa, Ethiopia, May 2-5, 2011.

Kenya Information, Communication and Technology Board. 2013. "Government Extends $1.6M Support for ICT Start-up Business". http://www.ict.go.ke/index.php/kictb-in-the-news/514-government-extends16m-support-for-ict-start-up-businesses (May 4, 2013).

Kerre, Wanjala B. 2000. "Science and Technology Teacher Education in Africa: Issues in the promotion of Scientific and Technological Literacy." http://portal.unesco.org/education/en/files/52553/11725002665Kerre.pdf/Kerre.pdf (October 22, 2011).

Kleiche, M., and R. Waast, eds. 2008. *Le Maroc scientifique*. Paris: Publisud.

Kolev, Alexandre, and Nicolas Sirven. 2010. "Gender Disparities in Africa's Labor Market: A Cross-Country Comparison Using Standardized Survey Data." In *Gender Disparities in Africa's Labor Market*, eds. S. J. Arbache, A. Kolev, and E. Filipak. Washington, DC: World Bank.

Krus, Glenda. 2006. *University-industry links: Lessons from South Africa*. http://www.scidev.net/en/opinions/universityindustry-links-lessons-from-south-afri.html. (July 25, 2010).

Kuria, Mike, Christopher Harnsert, and Mayunga Nkunya. 2011. *Regional Cooperation for Quality Assurance: The IUCEA/DAAD East African Quality Assurance Initiative*. GIZ.

Mamdani, Mahmood. 2007. *Scholars in the Marketplace: The Dilemmas of Neo-Liberal Reform at Makerere University, 1989-2005*. Dakar: CODESRIA.

Masanja, V. G. 2010. "Increasing Women's Participation in Science, Mathematics and Technology Education and Employment in Africa." Paris: United Nations Division for the Advancement of Women and UNESCO.

McKinsey Global Institute. 2010. *Lions on the Move: The Progress and Potential of African Economies*. McKinsey & Company.

Miguel, Edward. 2011. "Africa Unleashed: Explaining the Secret of a Belated Boom." *Foreign Affairs* 90 (6).

Mihyo, Paschal B., Abeeku Brew Hammond, Anselmo O. Makhoka, and Uirapi G. Tjihenuna. 2011. *The Role of Tertiary Education Institutions in the Development of Technical and Technological Capabilities for Employment Creation in Eastern, Southern and West Africa: Selected Case Studies*. ADEA Triennale 2012 working document.

Mkapa, Benjamin. 2004. "Indigenous Knowledge—a Local Pathway to Global Development." In *Indigenous Knowledge: Marking Five Years of the World Bank Indigenous Knowledge for Development Program*. Washington, DC: World Bank.

Mohamedbhai, G. 2011. "Strengthening the Research Component of the Space for Higher Education." AAU Conference of Rectors, Vice Chancellors and Presidents (COREVIP), Stellenbosch, South Africa, May 30-June 3, 2011.

Mugabe, John. 2008. *Centers of Excellence in Science and Technology for Africa's Sustainable Development: Towards New forms of Regional and Sub-Regional Networks*. http://www.nepadst.org/doclibrary/pdfs/doc08_112003a.pdf (June 15, 2011).

Mugabe, John. 2009. *Knowledge and Innovation for Africa's Development Priorities, Policies and Programmes*. Washington, DC: World Bank.

Namata, Berna. 2012. "Pan African University officially launched." *The East African*, January 2-8, 2012.

Nath, Chandrika. 2011. *Use of scientific and technological evidence within the Parliament of Uganda*. A joint report by the UK Parliamentary Office of Science and Technology, the Parliament of Uganda, and the Ugandan National Academy of Sciences.

NCST. 2010. *Mainstreaming Gender, Science and Technology Policies and Programmes in Kenya*. Report by the National Council for Science and Technology in collaboration with UNESCO Regional Bureau for Science and Technology in Africa.

Ndoye, M. 2012. "Education for Sustainable Development: Challenges, Issues and Prospects for Sustainable Development." *ADEA Newsletter* 20 (1).

Ngethe, Njuguna, George Subotzky, and George Afeti. 2008. *Differentiation and Articulation Tertiary Education Systems: A Study of Twelve Countries*. Washington, DC: World Bank.

Nordling, Linda. 2009. "Africa Analysis: Does Africa need a pan-African university?" http://www.scidev.net/en/opinions/africa-analysis-does-africa-need-a-pan-african-uni.html (July 25, 2010).

Nzau-Mutete, G. 2012. "What specific challenges must be overcome/opportunities seized to realize this possible future (e.g., in water, or agriculture/food Security, or health, etc.)?" Paper presented at the First African Conference on Science, Technology and Innovations for Youth Employment, Human Capital Development and Inclusive Growth, Nairobi, Kenya, April 1-3, 2012.

Oanda, C. 2013. "Youth Procurement Plan to Create New Billionaires." *The Star*, April 29, 2013.

Okuttah, Mark. 2012. "ICT innovations offer home-made solutions for Africa's growth." *Business Daily*, December 12, 2012.

Omwansa, Thomas. 2009. "M-Pesa: Progress and Prospects." Innovations/Mobile World Congress 2009. http://www.strathmore.edu/pdf/innov-gsma-omwansa.pdf orhttp://www.gsmworld.com/documents/INNOVATIONS-GSMA_FINAL-01-22-09.pdf (December 12, 2011).

Oyelaran-Oyeyinka, Banji. 2005. "Partnerships for Building Science and Technology Capacity in Africa." Paper prepared for The Africa-Canada-UK Exploration: Building Science and Technology Capacity with African Partners, London, UK, January 30-February 1, 2005.

Partnership for Higher Education. 2008. *Developing and Retaining the Next Generation of Academics*. Report of the Second University Leaders' Forum, Accra, Ghana, November 22-25, 2008.

Pouris, Anastassios, and Anthipi Pouris. 2009. "The State of Science and Technology in Africa (2000-2004): A Scientometric Assessment." *Scientometric* 79 (2). 297-309.

Public Universities Inspection Board. 2006. *Transformation of Higher Education and Training in Kenya to Secure Kenya's Development in the Knowledge Economy*. Report of the Public Universities Inspection Board. Nairobi: Republic of Kenya.

Sabaya, W. 2004. *Quality Assurance, Accreditation and Recognition of Qualification in Africa*. http://www.aau.org/wto-gats/papers/sabaya.pdf (August 29, 2011).

Safaricom. 2010. *2010 Annual Report*. http://www.safaricom.co.ke/annual_report_2010/index.html (December 15, 2011).

Safaricom. 2013. "M-Pesa agents." http://www.safaricom.co.ke/personal/m-pesa/m-pesa-agents (April 15, 2013).

Society for International Development (SID). 2011. *East African Integration: Dynamics of Equity in Trade, Education, Media and Labour*. Nairobi: SID.

Sommers, Marc. 2001. *Fear in Bongoland: Burundi Refugees in Urban Tanzania*. Oxford, New York: Berghahn Books.

Ssebuwufu, John, and Ludwick Teralynn. 2011. *Strengthening Linkages between Industry and Higher Education Institutions in Africa*. Association of African Universities and Association of Universities and Colleges of Canada, ADEA Triennale Document.

Stewart, V. 2012. "How Singapore Developed High Quality Teacher Work Force." http://asiasociety.org/education/ (May 4, 2013).

Tembon, Mercy, and Lucia Fort, eds. 2008. *Girls' Education in the 21st Century: Gender Equality, Empowerment and Economic Growth*. Washington, DC: World Bank.

The East African. 2012. "Q&A With Manoj Shanker: Tailor-made African IT solutions way of the future for industry." *The East African*, January 2-8, 2012.

The Economist. 2011. "Africa rising: The hopeful continent." *The Economist*, December 3-9, 2011.

The Economist. 2013. "Aspiring Africa: The world's fastest-growing continent." *The Economist*, March 2-8, 2013.

UN. 2008. *World Youth Report 2007: Young People's Transition to Adulthood: Progress and Challenges*. New York: United Nations, Department of Economic and Social Affairs.

UN. 2010. *World Programme of Action for Youth*. New York: United Nations, Department of Economic and Social Affairs.

UNECA. 2011. *Africa Youth Report 2011. Addressing the youth education and employment nexus in the global economy*. Addis Ababa: UNECA.

UNECA/IST. 2010. *A technology resurgence? Africa in the global flows of technology*. UNECA series on technology transfer for Africa's development. Addis Ababa: UNECA.

UNESCO. 2005. *EFA Global Monitoring Report: Literacy for Life*. Paris: UNESCO.

UNESCO. 2007a. Teacher Education Policy Forum for Sub-Saharan Africa Report. Paris: UNESCO Section for Teacher Education.

UNESCO. 2007b. *Science, Technology and Gender: An International Report*. Paris: UNESCO.

UNESCO. 2009. *EFA Global Monitoring Report. Overcoming inequality: why governance matters*. Paris: UNESCO and Oxford University Press.

UNESCO. 2010a. *UNESCO Science Report 2010: The Current Status of Science around the World*. Paris: UNESCO.

UNESCO. 2010b. *EFA Global Monitoring Report. Reaching the marginalized*. Paris: UNESCO.

UNESCO. 2011. *EFA Global Monitoring Report. The Hidden crisis: Armed conflict and education*. Paris: UNESCO.

UNESCO-UIS. 2006. "Women in science: Under-represented and under-measured." *UIS Bulletin on Science and Technology Statistics* 3 (November).

UNFPA. 2010. *State of World Population 2007: Unleashing the Potential of Urban Growth*. New York: UNFPA

UNFPA. 2011. *State of World Population 2011: People and Possibilities in a World of 7 Billion*. New York: UNFPA

Urama, Kevin, Nicholas Ozor, and Wairimu Mwangi, eds. 2010. *The State of Science, Technology and Innovation in Africa: Implications for Achieving the Millennium Development Goals*. Nairobi: ATPS.

Varghese, N. V. 2008. *Globalization of Higher Education and Cross-border Student Mobility*. Paris: IIEP.

Watkins, Alfred, and Michael Ehst, eds. 2008. *Science, Technology, and Innovation Capacity Building for Sustainable Growth and Poverty Reduction*. Washington, DC: World Bank.

Werquin, P. 2010. *Recognizing Non-Formal and Informal Learning Outcomes, Policies and Practices*. Paris: OECD.

Wolson, Rosemary. 2007. "Technology Transfer in South African Public Research Institutions." In *Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices*, eds. A. Krattiger, R. T. Mahoney, L. Nelsen, *et al.*, 1651-1658. Oxford: MIHR and Davis: PIPRA.

World Bank. 2000. *Higher Education in Developing Countries: Peril and Promise*. Washington, DC: World Bank/Task Force on Higher Education and Society.

World Bank. 2003. *Lifelong Learning in the Global Knowledge: Challenges for Developing Countries*. Washington, DC: World Bank.

World Bank. 2007. *Developing Science, Mathematics, and ICT Education in Sub-Saharan Africa: Patterns and Promising Practices*. World Bank Working Paper No. 101, Africa Human Development Series. Washington DC: World Bank.

World Bank. 2009a. *Africa Development Indicators 2008/09: Youth and Employment in Africa. The Potential, the Problem, the Promise*. Washington, DC: World Bank.

World Bank. 2009b. *Accelerating Catch up: Tertiary Education for Growth in Sub Saharan Africa*. Washington, DC: World Bank.

World Bank. 2010. "Kenya at Tipping point for Robust Growth Driven by the Telecommunication Revolution". Washington, DC: World Bank.

World Bank. 2011a. "Learning for All: Investing in People's Knowledge and Skills to Promote Development." World Bank Group Education Strategy 2020 Executive Summary. Washington, DC: International Bank for Reconstruction and Development/World Bank.

World Bank. 2011b. *World Development Report 2012: Gender Equality and Development*. Washington, DC: World Bank.

Yonazi, E, et al., eds. 2012. *The Transformational Use of Information and Communication Technologies in Africa*. Washington, DC, and Tunis: World Bank and African Development Bank.

Young, Terry A. 2007. "Establishing a Technology Transfer Office." In *Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices*, eds. A. Krattiger, R. T. Mahoney, L. Nelsen, *et al.*, 446-458. Oxford: MIHR and Davis: PIPRA.

Association for the Development of Education in Africa (ADEA)
African Development Bank (AfDB) – Temporary Relocation Agency
13 avenue du Ghana – BP 323 – 1002 Tunis Belvédère – Tunisia
tel: +216/ 71 10 39 86 – fax: +216/ 71 25 26 69
e-mail: adea@afdb.org – web site: www.adeanet.org