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# Applying Science, Engineering and Technology for African Competitiveness and Development

## KEY MESSAGES

- The direct link between Applied Sciences, Engineering and Technology (ASET) and economic growth is widely accepted.
- Most countries in Sub-Saharan Africa have made rapid gains in child survival and progress from primary to secondary school; however, just 8 percent of university-age youth are in university, and only 1 percent will graduate in a science or engineering field.
- This situation is now changing, with increased attention being paid to ASET by the African Union, NEPAD, UNESCO, and many others, and African research capacity is beginning to diversify in response to country demand.
- African countries need to devise customized ASET strategies that can support national strategies for economic growth and respond to pressing challenges, as well as collaborate on regional initiatives and institutions. In doing so, they can draw on rich lessons of experience.
- Science, Technology and Innovation can be measured by two sets of indicators: Output (achievements in knowledge generation) and input (trends in the enabling conditions for scientific and technological production).

In pursuit of the Millennium Development Goals, most African nations have significantly increased the likelihood that children will survive childhood, enter primary school and gain access to secondary education. As a result of science education efforts at the secondary school level, they are also more likely to develop an interest in science and mathematics. Yet today, less than 8 percent of the university-age cohort in Africa is fortunate enough to enter university. More importantly, only one out of every six students who enters university is likely to graduate in a science or engineering field (UNDP 2013: 188-189). That is just 1 percent of the university-age cohort.

However, attention is increasingly being paid to university education in applied sciences, engineering and technology (ASET). The direct link between ASET capabilities (as well as higher education more generally) and long term economic growth is now widely accepted.

Half of Africa's population is expected to be urban by 2030. This catalyzes the demand for applied science solutions to areas such as water and sanitation, power generation and supply, air quality and environmental preservation, and transportation and telecommunications. As this shift occurs, African research capacity, which has tended to focus on agriculture, is now starting to diversify into public health, industrial technologies, and business services. Robust economic growth and increasing foreign direct investment create a propitious environment for investments in ASET.

## Working towards a Common Goal

African countries are faced with a common task: to create and sustain relevant capacities for applied science, problem-solving engineering and technology that can support national growth strategies. The limited economic size of many countries suggests that an approach based on collaboration rather than competition may achieve the most in the long run. This is particularly true with regard to the expansion of PhD programs, quality research and specialized ASET capabilities.

A number of initiatives are underway. For example, the African Union (AU) approved a Science and Technology Consolidated Plan of Action in 2006, which seeks to expand research and development (R&D) capacities, improve policymaking and promote technological innovation. An

> ***Broadly interpreted, science, technology and innovation are now accepted as the foundation of economic change.***
>
> — NEPAD, 2010

immediate response by the Nelson Mandela Institution in 2007 led to the establishment of the African University of Science and Technology in Abuja, Nigeria. A second concrete outcome is the establishment of the Pan-African University, (PAU) a post-graduate training and research network of university hubs in five regions, with a strong emphasis on science and technology. Both NEPAD and UNESCO are working on improving and standardizing national monitoring capacity for science and technology.

## How Far has Africa Advanced in Science, Technology and Innovation?

Measuring national performance in science, technology and innovation (STI) is a comparatively new undertaking. STI performance can be measured in terms of outputs and inputs. Output indicators track achievements in knowledge generation, whereas input indicators reveal trends in the enabling conditions for scientific and technological production. The discussion below is based on a forthcoming study of ten countries: Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Rwanda, Senegal and Tanzania.

### OUTPUT INDICATORS

***PhDs***. A 2012 assessment of PhD education in Africa identified a host of challenges: funding shortages for students and institutions; limited institutional capacities; duplication of programs; poor quality student supervision; poor information sharing; constraints on academic freedom; weak links to industry; and inadequate responsiveness to national economic and social needs (MacGregor 2013).

At present, about 7 percent of the region's higher education students are pursuing postgraduate degrees. But the share of students engaged in PhD studies is far less. In Ethiopia, only one percent of the country's more than half a million university students are pursuing PhD studies (Ministry of Education 2013:241). In southern Africa (when South Africa is excluded), the total number of PhD students in the SADC countries was just 0.2 percent of the total university student population. On the bright side, a little over half of the 143 PhD degrees awarded by these universities in 2007 were in science, engineering and technology (Kotecha 2008:87).

***Scientific publications.*** The output of African scientific publications has increased over the past 15 years, tripling across 26 African countries from 10,082 in 1996 to 33,825 in 2010 (Arencibia 2012) with Algeria, Egypt, Kenya, Nigeria and South Africa contributing 86 percent of the total (NEPAD 2010). Between 2004 and 2008, Botswana, the Gambia, Kenya, Malawi, Mozambique, and Uganda achieved higher than world-average citation rates (Nordling, 2009). Scientific papers for eight of the ten study countries over the 2005-2009 period revealed that agricultural, medical and natural sciences plus engineering accounted for 74 to 93 percent of all publications (Table 1). The dominant category was medical and health sciences, reflecting the high research priority given to infectious diseases.

**Table 1. Distribution of scientific papers by disciplinary area (percent), 2005-2009**

| Disciplinary Area | Burkina Faso | Ethiopia | Ghana | Kenya | Malawi | Mozambique | Senegal | Tanzania |
|---|---|---|---|---|---|---|---|---|
| Natural sciences | 3% | 18% | 12% | 12% | 7% | 8% | 35% | 11% |
| Engineering, energy and technology | 2% | 2% | 4% | 2% | 2% | 2% | 5% | 3% |
| Medical and health sciences | 68% | 28% | 38% | 34% | 63% | 49% | 47% | 47% |
| Agricultural, biological, veterinary, and environmental sciences | 10% | 42% | 30% | 36% | 18% | 15% | 6% | 30% |
| *Sub-total* | *83%* | *90%* | *84%* | *84%* | *90%* | *74%* | *93%* | *91%* |
| Social sciences, law, business | 6% | 9% | 14% | 8% | 9% | 7% | 6% | 8% |
| Education | 0% | 0% | 1% | 0% | 0.5% | 0% | 0.5% | 0% |
| Humanities and arts | 0% | 0.3% | 0.7% | 0.5% | 0.1% | 0% | 0.3% | 0.3% |
| Other | 1% | 0.7% | 1% | 2% | 0.5% | 0.2% | 0.5% | 1% |
| **TOTAL PUBLICATIONS** | **751** | **2,408** | **2,022** | **4,971** | **1,047** | **462** | **1,333** | **2,570** |

*Source: NEPAD, African Innovation Outlook 2010, Table 5B.2.*

***Patents.*** An indicator of a country's ability to innovate is the number of new patents awarded to its citizens over a given time period. The region was awarded 843 patents during 2008-2012, which was a 33 percent increase over the 633 patents it obtained from 2000 to 2004. This is an encouraging trend, reflecting a number of factors including productivity of researchers.

## INPUT INDICATORS

The most common input indicators are higher education enrollments, postgraduate programs, academic staff qualifications, research funding, research infrastructure, and information and communication technologies (ICT) development. The level of women's participation in research and postgraduate studies should also be monitored.

***Enrollments.*** Enrollments in science, engineering and technology disciplines have declined over the past ten years in all study countries except Rwanda (Table 2). The percentage of university students pursuing doctoral degrees in Africa is rarely more than one percent of the total, and often much less. The number of postgraduate students as a portion of total tertiary enrollment varies from 0.3 to 7 percent among the ten study countries; the share of Master's degree students enrolled in sciences and engineering is 42 percent in Malawi, 65 percent in Mozambique, and 15 percent in Tanzania. Only 25 percent of postgraduate students are women (UIS/UNESCO, 2014).

***Staff qualifications.*** Training, recruiting and retaining PhD-holders has been a constant challenge, given the reality of the brain drain. Half of African doctoral students who study abroad are unlikely to return to their home institutions (IAU 2010).

**Table 2. Percent of tertiary education students enrolled in Science, Engineering and Technology disciplines, 1986–2012**

| | 1986-89 | 2003-2004 | 2010-2012 |
|---|---|---|---|
| Burkina Faso | 32 | 32 | 24 |
| Cote d'Ivoire | 28 | 26 | 25 |
| Ethiopia | 40 | 31 | 30 |
| Ghana | 42 | 35 | 25 |
| Kenya | 32 | 47 | 29 |
| Malawi | 17 | 59 | 54 |
| Mozambique | 61 | 37 | 22 |
| Rwanda | 26 | 20 | 33 |
| Senegal | 39 | 26 | -- |
| Tanzania | 9 | 34 | 14 |

*Source: World Bank 2000: Table F; World Bank 2009:49; UNESCO Institute of Statistics. UNESCO data from 1999.*

***Research funding.*** In 2006, the AU endorsed a target of one percent of GDP for R&D investment in its member countries. While there has been some progress, only Malawi, South Africa and Uganda invest more than one percent of their GDP in R&D (NEPAD 2010). Nigeria, with its oil resources and large university system dedicates just 0.2 percent of its GDP to R&D.

***ICT development.*** The quality and relevance of research activities in any nation depends significantly on its ability to retrieve information worldwide at non-prohibitive costs. African countries vary considerably with regard to internet access, computer ownership, and cellular phone ownership. At best (Kenya, Ghana, Senegal), roughly one out of ten families owns a computer. More commonly, it is one out of every 25 families or less. In seven of the ten study countries, half or more of the population has a cellular phone. In Ghana and Côte d'Ivoire cellular phone ownership is essentially universal.

***Institutional infrastructure for research.*** In terms of capacities for applied research only 35 R&D centers existed within 53 African nations in 2006 (ADB 2008). This will change as awareness of how applied research can fuel economic growth becomes widespread.

# What Makes a Good ASET Strategy?

A contemporary national ASET strategy should have the following features:

- Aligned national, sector and sub-sector strategies, including shared overall goals for innovation and science and technology development
- Pertinent PhD programs
- Effective staff development and retention policies
- Higher education curricula geared towards relevance
- Applied research legitimized by competitive funding
- Synergistic public, private and international partnerships
- A pipeline of science- and math-literate secondary school graduates

In addition, ASET programs (like other vocational, tertiary education, and research programs) flourish when there is an appropriate governance and financing framework covering the following:

- Governance mechanisms at the system level and at the institution level (including institutional governance and financial management mechanisms), which promote high quality and results.
- Funding mechanisms that promote efficiency and quality.
- Effective monitoring and evaluation.

Forming a national STI team helps countries create a network of resources and expertise that boosts their capacity for ASET. Commonly, the main players on an STI team are:

- University postgraduate programs
- A research university
- A national research council
- A competitive research grants program
- A PhD scholarship program
- Research libraries/internet (access to information)
- Industry-University linkage mechanisms
- A Parliamentary committee on Science &Technology

**Box 1. Lessons of Experience in Devising ASET Strategies**

Countries that decide to further develop their national capabilities for applied sciences, engineering and technology can draw upon suggestions and experiences generated by earlier such efforts. Strategies should concentrate on developing a few good quality scientific institutions that can serve as models for others. Additional considerations include:

- Scientific institutions should comprise more than just R&D centers or university institutes. They should also involve postgraduate programs, especially PhD programs.
- Institutional development should begin by focusing on niche areas of research crucial to the national interest where some critical mass of researchers and research output already exists.
- These selected scientific institutions should be provided with enough independent research funding so that they will not have to rely on contracted research for their survival.
- Scientific institutions should be autonomous enough to allow (i) scientific vision and values to coalesce into a true culture of research, and (ii) efficient, flexible management of human and financial resources.
- Investment in ICTs must be continuous.
- Training and technical guidance should be provided in the management of research and postgraduate programs.
- Modern and applied research works best when scientists and engineers from different scientific fields collaborate in multi-disciplinary research. Government ministries should not hold separate responsibilities for basic and applied research, and teaching and research should not be divorced from one another (World Bank 2007).
- Good channels of communication and linkages for cooperation should be pro-actively developed between scientific institutions and business enterprises.

## MORE ON THE TOPIC


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