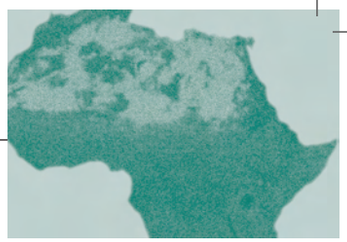
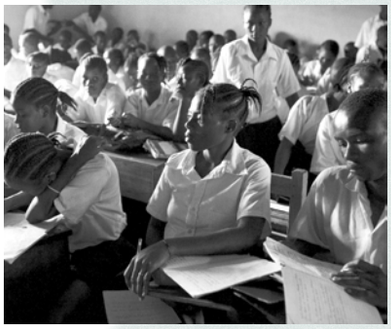


LESSONS IN LEARNING

BUILDING CAPACITY IN THE BASIC SCIENCES IS CRITICAL TO THE FUTURE SUCCESS OF AFRICA, SAYS PHILLIP A. GRIFFITHS (TWAS ASSOCIATE FELLOW 2000), PROFESSOR OF MATHEMATICS AND FORMER DIRECTOR OF THE INSTITUTE FOR ADVANCED STUDY IN PRINCETON, NEW JERSEY, USA. GRIFFITHS ALSO CHAIRS THE SCIENCE INITIATIVE GROUP (SIG), AN INTERNATIONAL TEAM OF SCIENTIFIC LEADERS AND ADVOCATES DEDICATED TO FOSTERING SCIENCE IN DEVELOPING COUNTRIES.



G. Gordon/UNESCO

"The deeper we seek, the more is our wonder excited."

Abdus Salam, Nobel Prize acceptance speech, 1979

Abdus Salam was a brilliant physicist and a devout Muslim who found harmony between his genius and his faith. He was a visionary who often observed that "scientific thought is the common heritage of mankind" and who fervently believed that each country, even – indeed, especially – the poorest, must develop its own scientific talent.

Salam contended that fundamental scientific inquiry could do more than bring wonder and self-respect to a developing nation. It could also help to drive the economic growth that was so desperately needed.

Salam was far ahead of his time. While a few economists, beginning with Robert Solow in the 1950s, reasoned that knowledge – especially scientific and technical knowledge – was a prerequisite for economic development, major donors and development banks have only recently incorporated this belief into their mandates and missions.

Over a decade ago, the World Bank, in its *World Development Report for 1998,* contended that knowledge is one of the most important "global public goods." A subsequent science and technology (S&T) strategy paper took this notion a step farther, asserting that scientific knowledge produces economic and social benefits. In today's knowledge-based world, it is widely accepted that S&T provides essential underpinnings for

Myriam Louviot/Wikipedia

Institutions of higher education provide the keys to basic research skills.

economic growth as well as the intellectual ground from which to address educational, environmental, health and other critical needs.

LEARN TO EARN

Institutions of higher education provide the keys to basic research skills in ways that can promote sustainable growth.

Yet, universities in developing countries, especially in Africa, are struggling to recover from decades of underfunding, civil unrest and brain drain. According to the *Webometrics Ranking of World Universities*, published twice yearly by the National Research Council of Spain, the highest-ranking university in Africa is the University of Cape Town, at number 349 (out of 4,000 universities included in the survey). The highest-ranking sub-Saharan university, outside South Africa, is Cheikh Anta Diop in Dakar, at number 3,038. Similarly, not a single African university outside of South Africa appears in the *Top 500 Universities* ranking published last year by Shanghai's Jiao Tong University.

A recent survey by the African Network of Scientific and Technological Institutions details the problems faced by these universities. On average, about 40% of the posts in S&T training institutions are vacant largely because of low funding, a poor image of science as a career, losses to HIV/AIDS and brain drain. The International Organization for Migration recently estimated that Africa lost one-third of its professionals to the developed world between 1960 and 1987, and that up to 23,000 academics and 50,000 middle and senior managers leave the continent each year. Only 50% of the staff in S&T training institutions have PhDs. The scarcity or absence of journals, textbooks, equipment and library facilities reduces the ability of staff to do research and publish. In only one of three departments across disciplines does more than one-half of the staff have office computers (in one university, the figure is 2%). More than one-half of all laboratory equipment (much of which is more than 25 years old) cannot be used for modern experimentation.

Specific examples of the challenges faced, which have been provided by the institutions themselves, include the following:

- *Faculty depletion*. At Makerere University, Uganda, the number of faculty positions in August 2007 was 1,796, but only 1,052 of those were filled. At the University of Dar es Salaam, Tanzania, for the first time, teaching positions were being filled in 2007 by staff with only bachelor's degrees. At Kenyatta University, Kenya, of 730 academic staff, only 31 are full professors and 48 are associate professors. At the University of Nairobi, Kenya, graduate students in physics are offered tenure in return for teaching. The same is true at Makerere.
- *Skewed age profiles*. A disproportionate number of lecturers in Africa are approaching retirement age.

At Kenyatta University, 28 of the 31 full professors are more than 50 years of age. At Kyambogo University, Uganda, only 22 of the 417 academic staff have doctorates and nine are past "mandatory" retirement age.

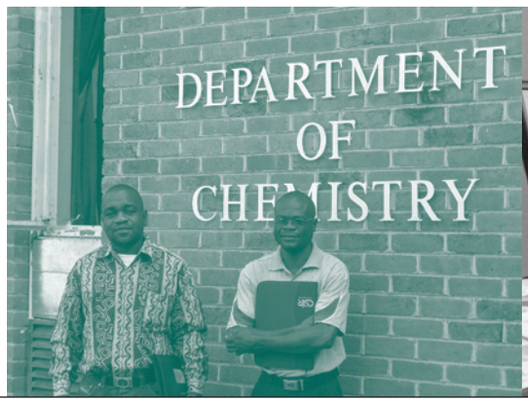
- *Demand for education*. Demand for education in Africa is soaring. So much so that universities cannot keep up with it. According to the *Global Educational Digest*, published by UNESCO, student enrolment in higher education in sub-Saharan Africa increased from 660,000 in 1985 to more than 3.4 million in 2005. This trend exacerbates the lack of professors and forces universities to turn to less experienced lecturers and tutors.
- *Low salaries*. While faculty salaries have improved at some institutions, such as the University of Nairobi, they remain too low to attract and retain new staff at many others. The average salary for full professors in all fields of study at Eduardo Mondlane University in Mozambique is USD1,000 a month.
- *Competition from private universities*. Soaring demand has encouraged the growth of private universities that emphasize such fields as business and accounting. Most private universities offer few or no courses in science or engineering. Those that do draw on staff from public universities whom they attract with higher salaries. For example, except for the director, the 11 members of the mathematics faculty at Eduardo Mondlane University also teach at private institutions. This doubling up on teaching responsibilities further reduces faculty time for research and mentoring. Nigeria has some 30 new private universities. Ghana has six public and 10 private universities, all founded within the past decade.

SYSTEMIC APPROACH

The situation for higher education in Africa might look bleak, but it is far from hopeless. Most institutions recognize the challenges they face, and some have begun to reform their policies. For example, to help address the country's chronic skills shortage, Zambia is considering eliminating the mandatory retirement age of 55 years for faculty in the sciences. The University of Nairobi has doubled faculty salaries twice in the past eight years.

As universities and donor organizations increase efforts to bolster basic higher education, it is important to remember that S&T will not by itself be sufficient to meet Africa's daunting challenges. We have seen how the rapid growth of the 'Asian tigers' in the 1970s and 1980s was not initiated by endemic research strength, but by imported technology. Basic research was emphasized only after a sound technological base had been created. The development of excellent primary and secondary school systems and broad-based training for faculty (often through study abroad) also provided a sturdy foundation upon which to build excellence in the basic sciences.

African leaders recognize that efforts to strengthen national capabilities in S&T depend on a systemic



Kisumu Ndogo/SkyscraperCity

approach. A conference held in Arusha, Tanzania, in May 2008 adopted the slogan "mainstreaming STI into the development process." Conference organizers saw their objective as strengthening not only S&T, but also 'innovation.'

For more than a decade, I have led the Science Initiative Group (SIG) at the Institute for Advanced Study in Princeton, New Jersey, USA. SIG is an international team of leading scientists dedicated to fostering science in developing countries. In seeking to build S&T capacity in developing countries, SIG has carefully examined other development models. Foremost among these are the programmes of TWAS and several originating in northern Europe, especially Sweden's International Science Programme (ISP).

Each of these programmes contains at least four major elements designed to develop systemic, and not just academic, capacity. These elements are local leadership, a national innovation system, government support and extensive networking with other institutions and the international scientific community. The approach focuses not only on the creation of knowledge, but also on fostering an environment in which knowledge is disseminated, used and transformed into new products and services.

Native-born scientists and engineers are best qualified to identify and address urgent national challenges. Governments are best situated to set general priorities, including aspects of S&T. Instead of determining research topics and strategies abroad, successful programmes should depend on national and local leaders for capacity building, education and research.

Science and technology add value to society only if they are part of a 'national innovation system' that increases the ability of a nation's institutions and infrastructure to create and commercialize new products for economic and societal use. Major elements of such a system include the following: human resources fostered by a national commitment to education at all levels; government institutions that sustain basic research, legal structures and physical infrastructure; and an entrepreneurial environment that nurtures small start-up firms, protects intellectual property and promotes the creation of venture capital.

An early goal of such a system, especially for poor countries with underutilized natural resources, is to create more value-added exports. As the private sector gains strength, other aspects of the innovation system will grow in importance. In sub-Saharan Africa, outside South Africa, countries have few small- and medium-sized enterprises, which can only thrive in a supportive environment. It is essential to begin planning for them by developing support mechanisms and laying the groundwork for technology-intensive clusters of academia, government and private enterprise that have proven so powerful for scientifically advanced countries.

Government enthusiasm for S&T-based development is crucial. This includes support at the presidential and ministerial levels, especially at ministries of finance. A significant example is the USD35-million Millennium Science Initiative in scientific research and education funded by the World Bank in Uganda. The priority status given to the programme by President Museveni and the Ministry of Finance provided early momentum to the effort, the primary objectives of which are to develop human resources and infrastructure for research, with complementary attention to university-industry linkages and support services.

Similarly, Rwanda has adopted an ambitious S&T

development programme, thanks largely to the personal involvement of President Kagame. In February 2008, the president addressed the plenary session of the American Association for the Advancement of Science (AAAS) annual meeting in Boston: "I believe in the power of science to transform our societies. But in Rwanda our institutions remain feeble. We have neither a strong private sector for demand, nor institutions to meet that demand. But we do have the will. For seven years we have been laying a sound foundation for S&T. The public sector will play a leading role while other pillars gain strength." Rwanda now spends 1.6% of its gross domestic product (GDP) on S&T and plans to increase this to 5% by 2021.

Other governments in Africa are beginning to display commitment to S&T. At the 2008 Arusha conference, Tanzania's Minister of Science and Technology, Peter Msolla, said his government "is determined to invest in STI" by focusing on research and development, retaining talent at home, and forging partnerships abroad. The responsibility for success, he stated, "lies primarily with national governments."

Science and technology add value to society only if they are part of a 'national innovation system'.

Even the best universities in sub-Saharan Africa lack a critical mass of students and faculty in fields of S&T. While these universities might have the will to build capacity, it will take time and resources to attract and train new students and faculty. A valuable complementary strategy is to link these scientists with related institutions and their peers in Africa and around the world.

The ISP's success, based on more than 45 years of experience, has emphasized long-term support for fellowships, equipment purchases and locally requested fields of study. It has curbed brain drain by the use of a 'sandwich model' that offers 1-year visits to Uppsala, Sweden, as long as the recipient remains affiliated with his or her home institution, where the degree is conferred. Lennart Hasselgren, who initiated ISP's programmes that now include chemistry, mathematics and physics, emphasizes the need for long-term support. ISP, for example, has funded one group for 32 years. Annual grants range from USD10,000 to USD140,000. ISP fellowships have helped to produce 58 doctoral and 246 master's theses, and 328 papers in international journals.

RISE PROGRAMME

Past experience has shown the power of knowledge-sharing.

Such sharing serves as the basis for the RISE programme developed by SIG, funded by the Carnegie Corporation of New York and managed jointly by SIG and the African Academy of Sciences. RISE is built on SIG's earlier experience with the Millennium Science Initiative, funded primarily by the World Bank.

The objective of RISE is to prepare PhD-level scientists and engineers in sub-Saharan Africa through university-based research and training networks. The programme supports five networks, each consists of universities in at least three countries. Each network is expected to grant a minimum of 15 PhD and master's degrees over four to six years.

An international selection committee chose the five networks from among 48 proposals from scientists in 29 countries. Each network will receive approximately USD800,000 over 30 months, with funding likely to continue for an additional three years.

The proposals vividly illustrated how many functional and imaginative African networks already exist in such critical areas as clean drinking water, renewable energy, geophysics, information technology and natural products. The impulse to collaborate is strong, and applicants appear to welcome the opportunity to form partnerships with groups that have complementary skills and expertise.

The networks, selected in fall 2008, are the following:

- African Natural Products Research and Training Network – AFNNET
- African Materials Science and Engineering Network – AMSEN
- Southern African Biochemistry and Informatics for Natural Products Network – SABINA
- Sub-Saharan Africa Water Resources Network – SSAWRN
- Western Indian Ocean Regional Initiative – WIO-RISE

All of the networks have moved ahead with energy and enthusiasm. Many of them enjoyed a head start, guided by past partnership experiences. Our objective is to make the RISE versions even more effective.

For example, in the Western Indian Ocean network on marine sciences, one node is in Mozambique, where participants are eager to get on with the task of modernization after years of ruinous civil war. They are especially keen to add RISE to a web of partnerships they have formed over the years.

According to Antonio Hoguane of Eduardo Mondlane University: "Long before RISE, we belonged to several networks and regional organizations. So the people in the marine sciences know each other and share interests. We have been part of UNESCO's Intergovernmental Oceanographic Commission (IOC) since 1982, and we have partners in Mauritius, Madagascar, Tanzania, the Seychelles, South Africa, and other communities around the western Indian Ocean. One of our RISE graduate students, Avelino Langa, will study geoinformatics under Dubi, focusing on fluid dynamics of coastal structures. We expect that he will develop the skills to advise not only our government, but also the governments of our partners, on coastal erosion and other issues."

There can be no economic advancement without the creation of knowledge.

Hoguane expressed many advantages of partnerships and networks, especially in sharing resources, instrumentation and people: "None of us can afford to have all the people we need in one country," he said. "Partnerships and networks also avoid duplication and ensure complementarity. They can help build common understandings that allow us to speak with a single voice when negotiating with donors or other organizations. This is critical for us, because other countries don't always understand African issues. For example, their idea of building capacity is to teach us their knowledge. Our problem is not so much a lack of knowledge as a lack of resources, including human resources. We know what we want to do and what we need. What we need are the resources to do it."

Likewise, positive benefits are already obvious in the water network, SSAWRN. One scientist who participated in this network was Francis Arimoro, a postdoctoral student who developed an interest in stream biology in his home country of Nigeria.

His primary research interest is to use aquatic insects as indicators of water quality. However, at his home institution, Delta State University in Abraka, his department had virtually no instruments – not even a compound microscope, which is essential to identify small insects.

Papaf Mwenyewe/SkyscraperCity

Support from RISE has given him the opportunity to work in a well-equipped laboratory, at Rhodes University in South Africa, where he is now adapting a stream bio-assessment protocol from an existing local system. He has written four papers on his work – two of them published – as well as a review and book chapter. He looks forward to applying his work at home in Nigeria.

The Southern African Biochemistry and Informatics for Natural Products (SABINA) network has also been built on a foundation of productive partnerships. One of its leaders is Zeno Apostolides, a professor of biochemistry from the University of Pretoria, who for many years has studied the chemistry of tea in partnership with the Tea Research Foundation (TRF) of Central Africa, in Malawi.

One of his collaborators has been Nicholas Mphangwe, a plant breeder at TRF. Producing tea, like other agricultural activities, has become a high-tech enterprise, requiring advanced skills. Mphangwe has an MSc from the University of East Anglia, but his mentor is preparing for retirement and has urged Mphangwe to earn a PhD. Until the advent of RISE, this was impossible financially. Mphangwe is now working in Pretoria with Apostolides and others, learning to identify genetic markers that will allow rapid selection of desirable tea strains.

One gratifying effect of these networks is to link enthusiastic but inexperienced students with senior mentors. For example, in early 2009 a young man named Lloyd Nyemba joined the Centre of Excellence in Strong Materials at the University of the Witwatersrand in Johannesburg, South Africa, as part of the African Materials Science and Engineering Network (AMSEN). A native of Zimbabwe, Nyemba had majored in mechanical engineering but had no opportunity to advance his career. He took a chance and followed his brother and sister to Namibia, where he met Frank

SCIENCE INITIATIVE GROUP

The Science Initiative Group (SIG) is an international team of scientific leaders and advocates dedicated to fostering science in developing countries. Its current projects are as follows:

- *The Carnegie-IAS Regional Initiative in Science and Education (RISE) develops human capacity through science and technology training and research in a regional context in sub-Saharan Africa, enabling individuals to use S&T to contribute to national and regional economic development.*
- *The Millennium Science Initiative (MSI) is an international initiative designed to build capacity in modern science and engineering. Highly adaptable to circumstances, the MSI achieves its mission through a variety of vehicles, among them competitively chosen centres or networks of excellence in scientific research and training.*
- *The Global Science Corps (GSC) will place scientists and engineers ("GSC Fellows") from developed countries at universities and research institutes in developing countries for one-year terms to share expertise and collaborate with local partners.*

For additional information, see sites.ias.edu/sig.

Julien Carnot/Wikipedia

Strengthening universities must be considered just a first step in capacity building.

Kavishe of the University of Namibia, who asked if he might be interested in working on carbon nanotubes in South Africa. Nyemba, who had barely heard of this lively new field, immediately said yes. He began his studies under Lesley Cornish at Wits and has since moved on to other cutting-edge research.

AMSEN has also helped Odilon Ilunga, a refugee from the war-torn Democratic Republic of Congo, who made his way to Namibia after working briefly as an engineer in a copper concentrating facility. His dream of moving ahead in his career was postponed when he was forced to stay in a camp for refugees. Nevertheless, he was able to gather a sufficient amount of materials to study and began to teach science to other refugees. He even started a small metallurgical lab to practice and demonstrate refining technique.

When Ilunga was finally allowed to leave after several years, he was offered a job in the remote copper mining town of Tsumeb, where he advanced rapidly to become co-manager of metallurgy. But he missed the academic and teaching environment he loved. So, in 2008, he journeyed to the University of Namibia. There he found Frank Kavishe, who was setting up the country's first faculty of engineering and needed talented engineers. Ilunga not only qualified for the graduate programme, but was the only metallurgist in Namibia. When the RISE competition was announced shortly after that, the University of Namibia was accepted as part of AMSEN, and Kavishe saw a natural fit. Ilunga would strengthen the network through his interest in purifying Namibian copper, while benefiting from using the advanced equipment at the University of the Witwatersrand, an AMSEN partner.

CHALLENGES AHEAD

The development of the RISE networks, of course, does not come without challenges. One challenge is language. In Mozambique, two of the students eager to work with SSAWRN have a tenuous command of English. One has sought out a tutor at a foreign consulate in Maputo; the other worries that the language barrier will limit his career, despite his determination. And RISE still lacks participants from Francophone countries.

Another problem is that students from institutions with weak infrastructures may not be able to continue their work at the same level when they return home. This is a worry, for example, of Agostinho Vilanculos of Mozambique, who plans to model rainfall in the Zambezi River basin. Although he is using a new technique to model stream flow from satellite cloud data, the Zambezi does not have the weather stations he needs to correlate his mathematical results with actual field conditions. A related problem is that students need 'bridge' support after returning home so that momentum does not flag and they can continue to keep up-to-date on their research and publish.

Some problems are more procedural, but no less troubling. These are caused by bureaucratic barriers that hinder the movement of students between countries, and variations in costs and requirements between institutions and countries. RISE has to strengthen its investment in administration to address these problems.

If there is a common weakness in the networks, it is a lack of access to the private sector and other potential partners outside academia. This is to be expected

in countries where technical skills at all levels have been neglected for many years. That is why the strengthening of universities must be considered as just a first step in capacity building.

In February 2007, the World Bank, which has taken a leadership role in STI capacity building in Africa, held a global forum in Washington, D.C., where many African scientists and development experts spoke about their experiences. Speakers emphasized innovative ways to develop technical and vocational skills, to boost the private sector's capacity to find, adopt and adapt existing technologies that are not being fully utilized, to use these skills and technologies to generate more knowledge-intensive, value-added goods and services, and to build post-primary education and scientific-research systems that contribute in meaningful and measurable ways to the national development strategy. The World Bank held a follow-up Forum in 2009, and is now preparing recommendations for further, more substantive steps in this area.

KNOWLEDGE FIRST

There can be no economic advancement without the creation of knowledge. Yet knowledge becomes economically valuable only when it is disseminated in a useful form. Each country must develop its own endemic capacity if it is to stay at the forefront of modern science, but it must also develop mechanisms for disseminating and using that knowledge to serve its own interests and those of the region as well. These dual objectives must be linked if sub-Saharan Africa is to compete globally.

The success of the RISE networks will rest largely on the determination of African governments. While many institutions and individuals will play essential roles, only governments can build and sustain the foundation of basic science that is needed to anchor and stimulate economic growth and to enrich society.

Once a strong foundation in basic science is in place, sub-Saharan Africa will be ready to take full advantage of its rich mineral resources, maturing political institutions, abundance of native talent and eager-to-help diaspora.

From such a foundation, young Africans will be able to earn degrees in mathematics, physics, chemistry and biology that will help sub-Saharan Africa to assume its rightful place at the table of nations. Young Africans, moreover, will be able to probe the "dazzlement" of science, narrowing the gap between the North and the South, and bringing sub-Saharan Africa closer to Abdus Salam's vision of attaining "a bounty and a grace" for which thanks can be rendered "with a humble heart". ■

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