SCIENCE & TECHNOLOGY
BUILDING CAPACITY FOR DEVELOPMENT
Recent issues of Development Outreach have highlighted topics that traditionally have not been included on the development agenda, for example, the relationship between corruption and development and human rights and development. Similarly, this issue looks at the connection between Science, Technology, and Innovation (STI) capacity building and the process of economic development.

A consensus has emerged in the world community that STI capacity development is an absolute necessity if countries are to be competitive in the global economy of the 21st century. This is especially true for developing countries that are searching for ways to lift themselves out of poverty. Governments, donor organizations, and NGOs are debating the question of how best to design and implement STI capacity building plans that are appropriate to the specific economic realities of a given country.

The World Bank and the World Bank Institute are participating in this effort through several programs and initiatives. In particular, they have provided support to the establishment of the African Institute of Science and Technology (AIST), a research and educational institute which is meant to have a transformational effect on the African economy by creating science and technology centers and cultivating a cadre of trained professionals. The Bank is also active in disseminating information on the subject and fostering an international dialogue among policymakers and practitioners to help promote the advancement of STI capacity building.

To this end, a Global Forum will take place in Washington, in February, to discuss strategies, programs, and policies for sustainable growth and poverty reduction through the development of STI capacity. We hope that this issue of Development Outreach, which is being released to coincide with the forum, will help carry the message to broader audiences. The magazine highlights topics that will be central to the discussions at the forum, such as infrastructure investment, education, STI local applications, commercialization of science, scaling up innovation, and more.

As the world explores new frontiers in Science, Technology, and Innovation, we welcome your feedback on a topic that will greatly affect our global future.
SPECIAL REPORT
SCIENCE & TECHNOLOGY FOR DEVELOPMENT

2 Building Science, Technology, and Innovation Capacity: Turning ideas into actions
Guest Editorial
ALFRED WATKINS, EGBE OSIFO-DAWODU, MICHAEL EHST, AND BOUBOU CISSE
Building STI capacity is essential for developing countries to compete in the global economy.

6 Engineering in International Development: Linking with infrastructure investments in Africa
CALESTOUS JUMA
Technological innovation in Africa must be implemented in the context of long-term development strategies.

10 Imitation to Internalization to Generation: The case of Korea
JUNGHO SONU
Korea achieved economic growth through S&T thanks to the high literacy rate, strong government initiatives, and the response from the private sector.

14 Science and Technology Education in African Development: Its key role
WOLE SOBOYEJO
The creation of research and educational institutes will have a transformational effect on the African economy by cultivating a cadre of trained professionals.

17 Poverty Alleviation and Economic Growth in Rwanda through S&T
ROMAIN MURENZI
A new Ministry has been created in order to strengthen the integration of S&T in all sectors of the economy.

20 Commercialization of Science: A key landmark for an efficient National Innovation System
PETER LINDHOLM
The case of a small community that was able, with the help of the Federal Government, to design and implement an innovative system to boost its economy.

24 Latecomer Strategies for Catching Up: Linkage, leverage, and learning
JOHN A. MATHEWS
Latecomer strategies consist in using advanced technologies that have been developed elsewhere and put them to business use at lower cost.

28 First-Rate Science and Modernization of the National Research System in Chile
CLAUDIO WERNLI
An overview of the Millennium Science Initiative (MSI) Program and its successful implementation over seven years.

32 Scaling Up Innovation: The GoForward Plan to Prosperity
THOMAS D. NASTAS
Strategies and lessons learned for small and medium enterprises (SMEs) to succeed in the competitive field of S&T development.

36 VOICES FROM THE FIELD
38 KNOWLEDGE RESOURCES
39 BOOKSHELF
40 CALENDAR OF EVENTS
building SCIENCE, TECHNOLOGY, and innovation capacity
WITH INCREASING FREQUENCY, officials in low and middle income countries are coming to the conclusion that they must build up their science, technology and innovation (STI) capacity in order to make demonstrable progress in achieving the Millennium Development Goals (MDGs); raise productivity, wealth, and standards of living by developing new, competitive economic activities to serve local, regional, and global markets; and address social, economic, and ecological problems specific to each country.

A wide array of Governments, ranging from Uruguay, to Vietnam, to Georgia, to Botswana, Kenya, Mozambique and Rwanda among others, are drafting science, technology, and innovation policies, establishing Ministries of Science, and investing more resources into targeted science development programs. Nigeria, for instance, is using part of its recent oil revenue windfall to create a 5 billion dollar endowment for science and technology in that country.¹ The African Union is convening a special summit in early 2007 devoted specifically to the question of STI capacity building and implementing its recently promulgated Science and Technology Consolidated Plan of Action.²

There is good reason for all this attention. For countries, rich or poor, to build and maintain their productive sectors in the face of global competition, local enterprises must be able to continuously improve their products and services—that is, to innovate. In all modern business activities from farming to manufacturing to product distribution, this ability to innovate is inevitably dependent on the successful application of technology, whether that means improved farm machinery or new business software. Governments must therefore promote the skilled human capital, competitive environment, and supporting institutions—universities, technical and vocational schools, research labs, standards bodies, and infor-
mation and communication infrastructure to name just a few—that make this enterprise innovation possible.

A common theme is the recognition of the need for domestic STI capacity in developing countries. Contrary to prior hopes, the scientific and technological (S&T) advances in industrialized countries have not been automatically or easily applied to the problems of the developing world. By building local STI capacity, developing countries can not only better absorb and adapt foreign technologies, but also develop local solutions to local problems.

In alignment with national efforts, STI capacity building has also been receiving renewed high-profile attention in international development circles. The Blair Commission Report and the UN MDG Task Force Report, to name just two of the more prominent recent international calls to action, both argue that building STI capacity should be elevated from a missing or peripheral element of the development agenda to an essential component of every country’s strategy for reducing poverty, achieving the Millennium Development Goals, and producing more knowledge-intensive, higher value added goods and services.

Frontier science or Science and Technology for national needs?

A NOBEL PRIZE FOR SCIENCE will do little by itself to alleviate poverty or generate new business in developing countries. Likewise, the contributions to new fields such as nanotechnology and genomic research will be constrained by the scale of available resources in all but a few developing countries. The research and development (R&D) budgets of most developing countries do not approach the size of the 7 billion dollars which Ford Motor Co. alone spends on R&D annually. It is therefore important for developing countries to strike the proper balance between supporting new scientific discovery and the application of S&T to pressing national needs.

The East Asian experiences over the last 40 years serve as an example. A now widely told story, the East Asian "Tigers," including Korea, Singapore, and now China, took a much different approach to building STI capacity than did countries in most other regions. While each country’s approach in East Asia was necessarily unique, they shared the distinction of not focusing initially on frontier science, instead focusing on building labor force skills through education at all levels, creating incentives and public institutions for discovering and adapting needed foreign technologies, effectively using foreign investment to create technological spillovers, and building focused projects for supporting the technology needs of industry.

Some Latin American countries, in contrast, spent heavily on building up advanced scientific institutions and research, but were largely unable to translate this spending into the types of innovations and new businesses in the private sector which lead to economic growth. Nor were these scientific undertakings often aimed at solving the problems associated with poverty in these countries.

Jungho Sonu’s article in this issue explains the approach the Republic of Korea took over the past 40 years by moving from technology imitation to internalization to generation, leading to its remarkable transformation into a knowledge-based economy. Claudio Wernli relates the success of the recent Millennium Science Initiative (MSI) program in Chile, which has applied that country’s scientific capacity to the needs of national industries with notable success. The MSI has been replicated in Brazil and local variations of the program are planned for several African countries including Tanzania and Uganda.

Building capacity by tackling problems

WHERE SHOULD A COUNTRY BEGIN when there are so many human and institutional capacities needed to use S&T effectively?

One approach is to develop STI capacity around specific problems. Take the earlier cited example of delivering clean water to a rural village. To make this happen, STI capacity is needed at various points: scientists to test water samples, engineers to design local piping systems, and skilled laborers and craftsmen to build and repair the wells and cisterns. From this standpoint, it is easy to see that a university should develop a hydrology program and vocational schools should train the craftsmen.

The same approach can be used for promoting enterprise innovation, by building capacity around the needs of sectors, using STI interventions at the appropriate links on the value chain. Policies must be carefully designed to avoid traditional pitfalls such as picking winning industries, subsidizing activities that should be conducted by the private sector, and central planning. For example, educational systems must be designed to be responsive to the research and human capital needs of the private sector, rather than having course offerings, curriculum, and research programs imposed on them by government planners.

To this end, an important capacity to build is that of policy makers. S&T is a complex area for governments to support. It often cuts across ministerial jurisdictions and responsibilities and calls for sophisticated policies and programs with complex incentives that must change as the country itself changes. There is also no single best model to use—many countries have used S&T successfully for development through very different approaches.
Strategic opportunities for capacity building

IN THIS ISSUE OF DEVELOPMENT OUTREACH, Rwandan Minister of Science Romain Murenzi, whose leadership has helped Rwanda become fully engaged in STI capacity building, provides specific examples of how that country is building science and technology capacity around that country’s problems and opportunities. In his article, Calestous Juma points out the opportunity for enhancing local engineering skills and institutions during a phase of renewed investment in African infrastructure. Africa has other opportunities for STI Capacity Building as well, including the ongoing worldwide demand for its commodities including oil, metals, and timber. Trade flows between China and Africa soared from $10 billion to $40 billion over the period from 2000 to 2005. Shouldn’t African countries take a page from the Chinese playbook and require technology transfer, local skills development, sharing of intellectual property rights, and joint ventures with local companies on technology adaptation projects in return for their natural resource exports? 

Along these same lines, foreign direct investment, whether in supplier companies or R&D facilities, does not offer the automatic technological spillover benefits as is often the hope and could be targeted with similar capacity building policies. For example, Vietnam is actively developing a legal framework that leverages foreign direct investment to foster capacity building in science and technology. 

Another opportunity involves the discussion surrounding “brain drain”, the loss of scientists and engineers trained in developing countries to higher-paying, more prestigious jobs in developed countries, which has become instead a discussion of brain circulation, acknowledging that flows of human resources go in both directions. As was seen previously in places such as Korea, returning scientists and engineers not only add talent to the labor market, but play a key role in explaining and promoting the benefits of STI capacity for meeting social and economic goals. Such returnees are essential in ensuring the long-term success of STI capacity building programs. In several African countries, the Diaspora is now starting to play this important role.

Research has demonstrated that more than salary, including prestige and opportunities for cutting-edge S&T work, play a role in determining the willingness of scientists and engineers to stay at home. Countries in Europe and Asia have created policies with these incentives to lure highly educated and skilled members of the Diaspora to return home, policies which can be modeled in other countries.

Wole Soboyejo’s article addresses this issue of building and maintaining scientific and technical talent. He cites the example of the African Institute for Science and Technology as a new resource in African higher education. The Institute expects to significantly leverage scientific talent of African Diaspora who are presently faculty of top international universities. Several such faculty have already committed to spending a proportion of their time at the Institute. John Matthews discusses how countries which are latecomers to many technology fields can turn that challenge into an opportunity through a strategic process of “linkage, leverage, and learning”.

Two other articles deal with the important issue of technology commercialization—turning scientific and technological innovations into successful businesses. Peter Lindholm explains how an economically depressed area of former East Germany was able to generate investment and new technology enterprises from its existing R&D capacity. Thomas Nastas draws from his experiences with Russian technology investing to offer a comprehensive approach that governments can take to improve technology commercialization. He makes the important point that governments may generate more economic growth promoting technology development based on existing comparative advantages rather than in crowded “high-tech” sectors.

A final important opportunity that needs to be mentioned is the emerging regional approaches to building STI capacity. In regions with many small countries, such as Central America or East Africa, it is clearly beyond each country’s individual capacity to be serious contributors in all scientific and technological fields. Rather, cooperation across countries, whether through regional “centers of excellence” or other means, makes clear sense. Many S&T problems, such as climate change or natural resource usage, cut across boundaries by their nature. Serious thought must be put into designing regional approaches to STI capacity building, but if well done, these approaches offer yet more opportunity to better harness STI capacity for development.

Alfred Watkins is Science and Technology Coordinator, The World Bank.

Egbe Osifo-Dawodu is Special Adviser to the African Institute of Science and Technology.

Michael Ehst is a Consultant on Science, Technology, and Innovation Capacity Building, The World Bank.

Boubo Cisse is Task Manager for the AIST project at the World Bank Institute in Washington.

This issue of Development Outreach benefited significantly from the early input of Robert Hawkins.

Endnotes
1 More information on the Nigerian S&T fund can be found at: http://www.scidev.net/News/index.cfm?fuseaction=readnews&itemid=2960&language=1
4 For some recent private sector R&D spending facts see: http://www.ft.com/cms/s/2/e966372-6771-11db-9ea5-0000779e2340.html
5 See http://www.economist.com/agendaldisplaystory.cfm?storyid=8126261
6 An article on one of China’s technology transfer policies can be found at: http://www.ft.com/cms/s/3c78d028-648e-11db-ab21-0000779e2340.html
7 More on recent Vietnamese science and technology policy initiatives can be found at: http://www.aasas.org/news/releases/2006/0516vietnam.shtml
Development is easier done than said. The era in which Africa's development was defined largely as a matter for discourse is coming to an end. The traditional focus on relief and emergency activities is being replaced by a new focus on competence-building to enable Africa to solve its own problems. In other words, more attention is being paid to investment in people and infrastructure rather than simply providing short-term palliatives aimed at reducing the visible symptoms of low levels of economic productivity.

The transition to a competence-based development cooperation strategy for Africa will entail a clear recognition of the role of infrastructure in Africa's development and focused investment in the associated engineering fields. In a departure from traditional approaches to capacity-building which have focused on independent, short-term training activities, I propose that new engineering programs be directly linked to strategic investments in infrastructure development. This shift will involve building capabilities in key areas related to production, project execution and technological innovation.
In the area of industrial production, for example, African countries will need to strengthen their production engineering and management capabilities. To effectively undertake project execution of investment projects, the countries will need to enhance competence for personnel training, pre-investment feasibility studies and project implementation. Finally, the countries will need to focus on innovative work related to creating new products and processes. Most of the effort will involve engineering and the associated management practices.

The focus on infrastructure in this article is not intended to exclude other economic activities and the associated engineering fields. Similar strategies could be adopted in manufacturing as well. I use infrastructure both as a strategic opportunity given renewed interest in this field as well as an illustration of the linkages between engineering and development.

Frontiers without engineers: Poor infrastructure

Poor infrastructure and inadequate infrastructure services are among the major factors that hinder Africa's development. Without adequate infrastructure, African countries will not be able to harness the power of science, technology and innovation to meet development objectives and be competitive in international markets.

Infrastructure promotes agricultural trade and integration into world markets. It is fundamental to human development, including the delivery of health and education services. Infrastructure investments also represent untapped potential for the creation of productive employment. For example, it has been suggested that increasing the stock of infrastructure by 1 percent could add 1 percent to the level of GDP. But in some cases the impact has been far greater: the Mozal aluminum smelter investment in Mozambique doubled the country's exports and added 7 percent to GDP. It created new jobs and skills in local firms.

Roads are critical to supporting input and output marketing, but the expansion of irrigation probably constituted the most important element of supportive investment. Emerging evidence suggests that in some cases low-quality roads have a higher impact on economic development than high-quality roads. All significant scientific and technical efforts require reliable electric power and efficient logistical networks. In the manufacturing and retail sectors, efficient transportation and logistical networks allow firms to adopt process and organizational innovations, such as the just-in-time approach to supply chain management.

The advancement of information technology and its rapid diffusion in recent years could not have happened without basic telecommunications infrastructure. In addition, electronic information systems, which rely on telecommunications infrastructure, account for a substantial proportion of production and distribution activities in the secondary and tertiary sectors of the economy. It should also be noted that the poor state of Africa's telecommunications infrastructure has hindered the capacity of the region to make use of advances in fields such as geographical information sciences in sustainable development.

Globalization of trade and investment demands that countries upgrade their technological capabilities as a source of competitive advantage. Infrastructure contributes to technological development in almost all sectors of the economy. It serves as the foundation of technological development; its establishment represents, in effect, technological and institutional investment. The infrastructure development process also provides an opportunity for technological learning.

Learning from experience

Contemporary development history offers a wide range of lessons on the role of engineering in development in general and in technological innovation in particular. These lessons range from the role of technical universities in economic reconstruction to the role of technological innovation in business incubation to the engineering role in the provision of health, education, and water services. Africa and its international development partners can benefit considerably from these experiences.

Engineers play an important role in addressing the challenges associated with eliminating poverty and hunger, as illustrated by the experiences of Latin America and Asia.

Capabilities in engineering determine the ability to provide clean water, good health care, adequate infrastructure, and safe food. Information and communications technologies (ICTs) can help expand primary, secondary, and tertiary education by facilitating distance learning, offering remote access to educational resources, and enabling other solutions. Many other technologies hold the promise of significantly upgrading the welfare of women in Africa by improving energy sources, agricultural technology, and access to water and sanitation, for example.

Many health interventions—including the treatment and prevention of malaria, HIV/AIDS, drug-resistant tuberculosis, and vitamin and other micronutrient deficiencies—require new treatments and vaccines. The production of generic medicines holds the promise of improving people's access to essential medicines. Building domestic competence in fields like chemical and process engineering is critical to expanding the technological basis for improving healthcare in Africa. Vector-borne diseases such as malaria remain problems in parts of Africa. Engineering-based approaches such as redesigning houses and remodeling landscapes are examples of what can be done to help reduce mosquito breeding and malaria transmission respectively. This would complement efforts to develop new anti-malaria drugs and vaccines.

Improved technological knowledge at the local level will be indispensable for managing complex ecosystems, such as watersheds, forests, and seas, and for helping to predict (and thereby manage) the impact of climate change and the loss of biodiversity. Emerging fields such as industrial ecology offer new opportunities for addressing ecological challenges.
Access to water and sanitation will require continuous improvement in low-cost technologies for water delivery and treatment, drip irrigation, and sanitation.

Technological innovation is becoming equally critical in the management of freshwater resources. So far much of the attention on freshwater has focused on market-related issues, such as privatization. Innovation-related responses are just starting to emerge. For example, concern over water scarcity in agriculture is generating interest in alternative approaches that reduce the amount of water used to produce a unit of grain. Attention is also now turning to the development of drought-tolerant crops using both conventional breeding methods and genetic engineering. These applications need not rely only on modern technologies.

But technological innovation can only have the desired impact if it is placed in the context of long-term development strategies, especially those associated with greater regional diversity and experimentation. In this regard, regional integration efforts across Africa represent a major step in creating space for greater application of technological innovation in the implementation of the MDGs in particular and the transition toward sustainable development in general.

Identifying strategic opportunities

A STRATEGIC APPROACH in building up engineering capabilities in Africa is to link training programs to infrastructure projects in growing fields. For example, the expansion of ICT infrastructure provides unique opportunities for setting up training programs in electronic engineering. Similarly, expansion of power supply facilities could be used as a platform for creating linkages with training facilities in electrical engineering and related fields.

For example, expanding geothermal energy production in Eastern Africa (covering Djibouti, Eritrea, Ethiopia, Kenya, Tanzania, Uganda and Zambia) could be linked to engineering and environmental programs in various universities. Using existing technologies, the region has the potential to generate over 2,500 MW of electricity from geothermal energy, compared to the current global output of 8,100 MW. The installed capacity of Kenya and Ethiopia is about 65 MW. Expanding production in the region could be directly linked to the development of related engineering and other sciences.

Transportation projects also provide similar opportunities. For example, the Maputo Corridor is a joint initiative of South Africa and Mozambique, aimed at addressing the poor state of transport infrastructure between the Indian Ocean port of Maputo in Mozambique and the industrial interior of South Africa. The initiative represents a new opportunity to create linkages with other sectors.

The plan’s focus has included upgrading and constructing road links from Witbank to Maputo; improving rail facilities from Maputo to Johannesburg, together with lines connecting Maputo to Zimbabwe and Swaziland; updating Maputo’s port and harbor operations; and setting up a new, integrated border post to facilitate movement between Mozambique and South Africa. It also included improving telecommunications facilities, as well as related non-transportation investment such as the Maputo iron and steel plant, which will use natural gas from Mozambique’s Pande fields. The diversity of the technology-based activities within the parameters of the Maputo Corridor project illustrates its scope.

Efforts should therefore be directed at providing support for institutions of higher technical learning (especially in engineering), as well as academies of engineering and technological sciences, professional engineering and technological associations, and industrial and trade associations. While primary education has been the focus of donor community attention for decades, secondary higher education and research are only now beginning to gain policy attention in development circles.

African countries also need to enhance their own ability to develop, operate and maintain infrastructure services. Foreign construction and engineering firms will continue to be the main sources of technological, organizational and institutional knowledge for infrastructure development. But governments in African countries should devise policies to encourage technology transfer and build local capabilities in infrastructure projects.

Research and development (R&D) activities for the development, operation and maintenance of infrastructure should also be promoted, and linkages should be established with both domestic and overseas research networks. Given their strategic importance, research facilities need to be defined as part of Africa’s critical infrastructure and managed as such. Existing research facilities can be networked as part of regional research cooperation. Not only will this reduce duplication in the availability of such facilities, but it will also enhance mobility and cooperation among researchers.

Infrastructure services may be provided through combinations of public and private enterprises, while taking into account the needs of the poor. Governments may reduce their role as producers of infrastructure but retain their roles as regulators, financiers, suppliers and even competitors of private providers. Whatever roles they play, governments need to recognize that different types of infrastructure require different policies and approaches.
Different types of infrastructure have different technologies and organizational arrangements. Governments may need to assume a direct role in certain infrastructure projects if they see strategic importance in fostering the transfer and building up of local capability in the required technologies. In planning and implementing infrastructure projects, efforts should be made to harness the enthusiasm and drive of young professionals, many of whom are looking for an opportunity to serve the African world.

Full steam ahead

SOLVING AFRICA'S PRESSING CHALLENGES will require concerted efforts that will involve close cooperation between governments, industry, academia and civil society. It will also involve experimentation. There will be a lot of failed attempts. The critical element is promoting mutual learning among all development partners. It is only through experimentation and learning that we can reduce the costs of errors and enhance the benefits of innovation. The set of options for action provided can be implemented in the order they are given. But the most urgent ones involve engaging the engineering community, recognizing their contributions and inspiring the next generation.

C aestous Juma, FRS, is Professor of the Practice of International Development, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University.

This article has been excerpted from “The 2006 Hinton Lecture,” Royal Academy of Engineering, London

1 I want to thank Keith Davis and Philip Greenish (Royal Academy of Engineering, London) for inspirational conversations that helped shape this paper. I also want to thank Wm. Wulf and George Bugliarello (US National Academy of Engineering, Washington, DC), Lee Yee-Cheong (World Federation of Engineering Organizations, Paris), Tony Ridley (Imperial College London), Graham Allison, John Holdren, Henry Lee and Robert Frosch (Kennedy School of Government, Harvard University), Alice Amsden (Massachusetts Institute of Technology, Cambridge, USA), David Curry (davidcurryAssociates, Philadelphia, US) and Caroline Wagner (Georgetown University, Washington, DC) for their guidance on the importance of engineering in development. I am also grateful to Jeff Sachs (Earth Institute, Columbia University, New York), Lorna Butler (Iowa State University, Ames, USA) and Wilf Stevenson (The Smith Institute, London) for giving me earlier opportunity to outline some of the ideas developed in this paper. Finally, I am indebted to Apiwat Ratawanawara (Massachusetts Institute of Technology, Cambridge, USA) and Bob Bell for their valuable input into this paper.

2 A number of key terms used in this paper require clarification. “Africa” is used in this report to mean “Sub-Saharan Africa”. “Engineering” means the application of scientific and technical knowledge to solve specific problems. “Competence” denotes the ability to perform specific tasks and is used in this paper to reflect the practical nature of Africa’s development challenges. It is a subset of the larger concept of “capacity development”. The word “capacity” is often defined by the United Nations to mean the “ability of individuals, organizations and societies to perform functions, solve problems, and set and achieve goals,” Whyte, A. 2004. Landscape Analysis of Donor Trends in International Development. A Rockefeller Foundation Series, Issue 2, Rockefeller Foundation, New York, USA, p. 24. “Infrastructure” is used here to mean the facilities, structures, associated equipment, services and institutional arrangements that facilitate the flows of goods and services between individuals, firms and governments. Infrastructure therefore includes: public utilities, such as energy, telecommunications, water supply, sanitation and sewerage, and waste disposal; public works, such as irrigation systems, schools, housing and hospitals; transport sectors, such as roads, railways, ports, waterways and airports; and research facilities such as laboratories and related equipment. Infrastructure services include the provision, operation, and maintenance of the physical facilities of the infrastructure.


5 A recent study of China shows “that low-quality (mostly rural) roads have benefit-cost ratios for national GDP that are about four times greater than the benefit-cost ratios for high-quality roads. Even in terms of urban GDP, the benefit-cost ratios for low-quality roads are much greater than those for high-quality roads. As far as agricultural GDP is concerned, high-quality roads do not have a statistically significant impact while low-quality roads are not only significant but also generate 1.57 yuan of agricultural GDP for every yuan invested. Investment in low-quality roads also generates high returns in rural non-farm GDP. Every yuan invested in low-quality roads yields more than 5 yuan of rural non-farm GDP,” Fan, S. and Chan-Kan, C. 2005. Road Development, Economic Growth, and Poverty Reduction in China. Research Report 138, International Food Policy Research Institute, Washington, DC, pp. vii-viii


Imitation to Internalization to Generation

The case of Korea

BY JUNGHO SONU

IN THE MIDDLE OF THE 20TH CENTURY, mass production of transistor radios was started in Korea, purely based on national technology. The technology for the transistor radio at that time was primitive, so much so that even high-school students could make a simple transistor radio as a class project. At the beginning of the 21st century, just 50 years from producing the first transistor radio, Korea has become a world leader in the production of semiconductors, flash memory, ships and LCDs. It also produces the fifth largest number of automobiles in the world. Korea’s trade volume has reached $600 billion per year, which is 12th among the world’s countries.

It is surprising that Korea, which is a small and densely populated country (98,000 km²; population, 46 million), could succeed economically to this extent over the past 40 years. Koreans have always relied on the role of education in developing their own individual economies, and that of the nation. This is due to the belief that education is the only means to upgrade one’s social status. Even after the Korean War in 1953, parents sent their children to school and spent a major part of their assets for education. The UNESCO statistics show that Korea’s
primary school enrollment in 1960 was at 94 percent, which is much higher than expected given the country's income level. In addition, the Korean economy was triggered in the early 1960's by strong government policies designed to alleviate poverty. Once the economy started to roll, it continued.

The development of science and technology played a significant role in this economic growth. Starting with copying foreign products, Korean industries became competitive because of low labor costs. Jinzoo Lee (1988) categorized the development of technology in three stages such as imitation stage, internalization stage and generation stage. During the imitation stage, foreign technology imitation is the predominant means of acquiring competitive technologies for the market. The internalization stage starts when local engineers are capable of developing products or constructing new plants through indigenous efforts, or when domestically manufactured products become technically superior to products manufactured initially. The generation stage begins when the nation is capable of introducing market-leading products and state-of-the-art core technology.

The imitation stage (1960 through 1980)

YONGWON LEE (2004) characterized the development of science and technology during the 1960's and 1970's as a stage of imitation. The Korea Institute of Science and Technology (KIST), the first modern, integrated technical center, was established in 1966. The Ministry of Science and Technology (MOST), whose function was to integrate plans for S&T development, coordinate governmental R&D, as well as international S&T and research on nuclear energy, was established in 1967. The building of S&T infrastructures continued throughout the 1970's. The Technology Development Law and the Engineering Services Promotion Law were enacted in 1972. The Korea Advanced Institute was set up in 1971 to carry out high-caliber masters and doctorate programs. Many other specialized research institutions funded by the government were established in the 1970's.

The Korean Government invested a larger portion of its budget in S&T compared to other developing countries at the time. The government budget for S&T promotion increased from 0.18 percent of GNP in 1964 to 0.30 percent of GNP in 1970, and 0.37 percent in 1980. The proportion remained at that level until the 1990's. Korea was also the first developing country to have a ministry-level administration for S&T.

It is well known that S&T policy, the supply-side of technology, played only a minimal role during the imitation stage because private-sector demand for R&D was almost nonexistent. Nevertheless, policymakers believed in investing in S&T. Government-Funded Research Institutes (GRI) had full autonomy in the allocation of funds earmarked by the government. Progress would not have been possible without the complete trust of the government.

The major contribution of the GRLs during this period was to secure S&T personnel for the absorption and assimilation of foreign technology and to carry out contract research for the private sector. This alone may not have been sufficient to explain the returns from the resources allocated to the GRLs. Investments in the GRLs during the 1960's and the 1970's paid off for other reasons. GRLs attracted many Korean scientists and engineers from abroad who otherwise would have not returned. Many of them later played key roles in the development of the heavy and chemical industries and high-tech industries. GRLs also contributed to heightening the social status of scientists and engineers. They received high salaries and enjoyed a high degree of social prestige. As a result, engineering and science-related university departments attracted the best students.

To foster qualified researchers and create a competitive environment among universities, the Korea Advanced Institute of Science and Technology was established in 1971. The Institute was supported by the government until it could stand on its own, on a competitive level with the top-tier engineering colleges in the Western hemisphere. Time magazine reported in 2004 that the Institute ranked 37th in the IT field and its engineering department was ranked number 1 by Asia Week magazine. The Institute spent about $100 million for research in 2004.

Another major step toward enhancing the research capability of Korean universities was to establish the Korea Science and Engineering Foundation (KOSEF) under the Ministry of Science and Technology in 1977. This organization is similar to the NSF in the USA. KOSEF offers basic and applied research, as well as long-term research fellowships, up to 9 years. The Foundation allocated about $350 million to universities in 2004.

Internalization stage (1980's)

AFTER A DECADE of imitating foreign technology, the industry realized that copied technology could not compete with foreign advanced products. In order to advance technology development, it promoted internalization of technology. The following table shows how the ratio between government and private R&D expenditure has changed from 1963 to 2001 (Yongwon Lee 2004).

In 1963 the dominant portion of research expenditure was carried out by government, but the ratio started to reverse in...
1980’s. R&D expenditure by the private sector overrode the expenditure by the government in 1990 by 8:2. Due to the transfer of major research activity to the private sector, the government made R&D policies more effective and precise and, at the same time, encouraged the private sector’s active participation in technology innovation.

Tax incentives for R&D were extended. Tax credit for R&D was excluded in accounting the upper ceiling of the total tax exemption a firm could receive under corporate taxation. Custom duties for R&D equipment were either lowered or waived. Tax credit for corporate expenditures on human resources development was introduced.

Policy loans to support technological development were expanded, despite the fact that policy loans in general were shrinking at that time.

The national R&D program was established during this period to enhance the competitive environment among researchers in universities, national research institutes and the private sectors. It was the first time in science and technology history that a major direction in R&D was established at the national level.

One of the most expensive S&T projects during this stage was the construction of Daeduk Science Town located near the city of Taegon. One reason for this project was to relocate the Government Research Institute (GRI) to Daeduk. Many GRIs were located either in Metropolitan Seoul or the Changwon industrial complex. The primary purpose of the project was to encourage mutual cooperation among the GRIs.

**Generation stage (1990’s and after)**

Both the government and industry realized that an effective policy was required to enhance cooperative research between universities and industry, because 80 percent of the nation’s research capability was with the universities. The first major step was the creation of Science and Research Centers (SRC) and Engineering Research Centers (ERC) at universities in 1990. The main objective of the SRC and the ERC was to establish cutting-edge research capability at the university. Long-term projects were also supported, up to 9 years, and the ERC was incorporated into industry. The project was very successful. It allowed high-end research projects to be carried out, while high-quality manpower was supplied to the industry.

Another significant change that took place at this stage was the diversification of government R&D programs. Many ministries established R&D programs of their own: the Ministry of Information and Telecommunication, the Ministry of Agriculture and Forestry, the Ministry of Environment, the Ministry of Health and Welfare, and the Ministry of Ocean and Fisheries. This indicates that R&D policy was then considered by the ministries as a viable instrument in carrying out policy objectives. Among these, the R&D program hosted by the Ministry of Information and Telecommunication is by far the largest and most important. The Telecommunication Technology Program, started in 1992, has brought about many successful results. R&D projects such as the Broadband Integrated Service Digital Network (B-ISDN) and the Code Division Multiple Access (CDMA) are good examples. These programs have two advantages over other programs. First, it is possible to put a relatively large amount of money in a narrowly defined area because funding originates not from the government budget but from the proceeds of the Korea Telecommunications Corporation. Second, marketing of the R&D results is supported by the procurement policy. The ministry is the largest buyer of telecommunications equipment.

**How has Korea been changed during the last 40 years?**

As shown in Figure 1, the GDP/capita has grown from $150 in 1960 to $16,000 in 2005. Considering purchasing power, the GDP/capita is even higher than $19,000 according to the World Development Indicators published by the World Bank (2006). Total volume of trade ranked 12th in the world and amounted to $600 billion in 2005. These numbers represents Korea’s successful development during the past 40 years.

It can be noted that the GDP increased sharply in the middle of the 1980’s and early 1990’s. This occurred at the end of the internalization stage and the beginning of the generation stage. Industry started to realize that the new technology, developed internally, was competitive on the international
market and acquired confidence in technology development. At this stage, the nation had changed the export market from labor-intensive products to high-technology products. Main products for export were container ships, LNG bulk carriers, LCD panels, DRAM, mobile phones, high definition TV, functional textiles, automobiles, etc.

This proves that the development of science and technology is crucial in the development of the national economy.

The expenditure for research and development increased rapidly since 1990, and was almost doubled during the last decade. There was a wide consensus among all sectors of Korean society that the development of science and technology should play a crucial role in the national economy.

Figure 2 shows the variation of R&D expenditures during the last 40 years in Korea. Even in the internalization stage, the R&D expenditure was very small compared to that of the generation stage since 1990. The current goal is to make the ratio of the R&D expenditure to GDP 3 percent. One of the big features of R&D policy during the last decade was the creation of large-scale research projects and integrated planning at the national level. The Presidential Advisory Council on Science and Technology has been strengthened and has full control of national-level research projects.

Nano-technology (NT), Information Technology (IT), and Bio-technology (BT) are the main axis of the government initiative on research and development at the generation stage.

Figure 3 shows the relative position among 12 OECD countries in terms of the ratio of R&D expenditure to GDP and number of researchers per 1000 employment. This figure clearly shows that Korea is in a good position in expenditure for research but should make an effort to expand the number of researchers. Finland and Japan are in a better position, but other countries are close to Korea's. Just 20 years ago, Korea was not in the position to even compare research and development activities with these OECD countries.

Concluding remarks

Korea is known to be the first country in economic history whose world trade became the 12th in volume over 40 years starting from such an initially low position as Korea. It may not be possible to summarize in a single sentence which factors created the rapid development of the national economy, but one may argue that it was a combination of the high literacy rate, strong government initiatives, and the positive response from the private sector. In other words, in order to succeed, the government had to develop an intensive education system, a qualified manpower program for research and development, and promotional programs for the related industries. The effective execution of government's initiatives remains the best way to alleviate poverty in the nation. Just as important is the way people think: "we can do it."

Jungho Sonu is University Chair Professor, Myongji University, Seoul, Korea.

References
Lee, Yongwon, "The role of S and T in Korea's Industrial Development", personal communication, 2004
Sonu, Jungho, "50 years of Science and Technology in Korea," presented at the seminar organized by the World Bank, June 2005.
Science and Technology Education in African Development

Its key role

BY WOLE SOBOYEJO

This article examines the key role that high level science and technology education can play in the development of a knowledge-based economy. This requires a critical mass of well-educated workers that can operate in globally competitive industries. However, unfortunately, the supply of such highly skilled workers is currently limited within the African context. This is particularly unfortunate given the large number of Africans that graduate from universities every year. The problem has also been exacerbated by the brain drain that has occurred in Africa over the past 20-25 years.

So, how can a critical mass of globally competitive workers be developed, who can become job creators and leaders within the African economy? This is really the key question that must be considered within the context of a short- and long-term strategy for education. This article will explore possible strategies for the development of a knowledge-based economy that would impact the global economy. These strategies should be implemented within the context of an integrated tertiary education strategy, coupled with technology transfer and innovation. They should also address current and future industrial/business needs and evolve as the country’s needs increase in Phases I and II.
The approach

IN PHASE I, a relatively small number of high quality institutions or centers of excellence can provide the required number of highly skilled individuals to the African economy. One approach to doing this is the development of an African Institute of Science and Technology (AIST). The AIST initiative is an example of a public/private partnership that will bring a world-class institution to Africa by 2007. The objective is to establish Institutes of Science of Technology that are similar to the Massachusetts Institute of Technology (MIT) in the U.S., or the Indian Institutes of Technology (IITs) in India. Such institutions had a transformational impact on the economies of the U.S. and India, respectively. The hope is, therefore, to develop institutions that can have similar effects on the African economy within the next few decades.

Within this context, the concept of the AIST has emerged as one of the ways in which Africa can use science and technology to promote economic growth and develop solutions to African problems. The goal is to establish major institutes of science and technology in Sub-Saharan Africa. The first of these will be in Abuja, Nigeria. This campus will offer undergraduate and graduate programs that focus on science and technology within the context of Africa and the need to develop a knowledge-based workforce.

So far, President Obasanjo has pledged his support for this initiative as Head of the African Union and President of Nigeria. Minister El Rufai of The Federal Capital Territory (FCT) has allocated 550 acres of land to the AIST-Abuja campus within the Abuja Technology Village (ATV). A secretariat building has also been provided by the FCT to guide the Pan-African activities of the AIST. And the World Bank and WBI have provided encouragement and support for the AIST initiative.

The AIST-Abuja campus will accept the best and brightest students through a Common Entrance Exam that will be offered in African countries. The initial goal is to build up a student body of 3000, and then increase the number to 5500 students. Students will be accepted irrespective of their ability to pay. The AIST will, therefore, use its endowment to support the best and the brightest students, hoping that such students would have the intrinsic talent to really transform Africa. Furthermore, although the name of the AIST suggests science and technology, the goal is to develop balanced individuals with leadership potential. Therefore, the students will be required to take courses in finance, entrepreneurship, languages, arts and culture, and global development.

Interdisciplinary research and education centers will be organized in: a) Petrochemical engineering; b) Materials; c) Water resources and environmental engineering; d) Mathematics and computer science.

The students will be taught by the best African scholars from Africa and the Diaspora. The professors will also be compensated well to ensure that their primary focus will be on academics.

It is anticipated that many of the initial faculty will come from the Diaspora, where there are African professors teaching at leading universities in the world. In addition to a core faculty of permanent faculty, Visiting Professors from African universities will have the opportunity to teach and do research at the AIST. This combination of visiting and permanent faculty will ensure highest-quality standards in teaching and research.

Each undergraduate student that attends the AISTs will have the opportunity to receive a hybrid education. This will include a degree in their major subject(s) from one of the core departments, and diplomas in interdisciplinary areas of general interest to the student. For example, a student could graduate in an engineering subject, with a diploma in arts and culture. The hope is that such a well-rounded person is likely to be better prepared for leadership than a student with a purely technical focus. Similarly, a student may graduate with a degree in applied science with a diploma in entrepreneurship and finance. In this case, the hope is that such a student would be more inclined towards scientifically-driven technological entrepreneurship.

At the graduate level, top students will be selected from all African countries. It is recognized that some of these students may come with deficiencies in their computer skills and some aspects of their overall preparation for graduate school. The first year of the graduate program will, therefore, fill in such deficiencies and bring all the students to a uniformly high level. Beyond this, the second year of the Masters program will provide the students with a graduate level understanding of core/interdisciplinary subjects, and an initial exposure to research methodologies. It is anticipated that up to half of the students will graduate and move on into the workforce at the end of the Masters programs in engineering, applied science and management.

The remaining half of the graduate students will then move on to receive a PhD over the next 2-3 years. The goal will be to expose such students to the frontiers of knowledge in their core subjects, along with possible approaches to interdisciplinary learning and research at one of the interdisciplinary institutes of the AIST. Each PhD student will also be required to act as an Assistant in Instruction (AIs) in under-
graduate courses that are offered by the AIST. The AIs will be designed in a way that will help the PhD students to develop their teaching styles and philosophies before going on to become faculty members at the end of their PhD programs.

At every level of the AIST, the goal will be to create an exciting environment that stimulates innovation. Therefore, there will be design and innovation competitions, and students and faculty members that come up with new ideas will receive awards and will be encouraged to start companies that commercialize such ideas. Venture capitalists will be invited to campus to interact with such innovators in ways that will stimulate the transfer of technology from the AIST to the marketplace. In this regard, the location of AIST-Abuja within the Abuja Technology Village (ATV) will provide a natural environment for the incubation of new companies.

Beyond the nucleation of new companies, AIST-Abuja will develop strong links with many of the industries/businesses within Africa. These links will include: industrial advisory boards to guide the activities of departments and interdisciplinary institutes; sponsorship of research and development; sponsorship of innovation and technology transfer to industry. As such, an office of technology transfer and licensing will be developed to manage the relationships between AIST-Abuja and industry in Africa and the rest of Africa. The hope is to have a push-pull relationship, with industry pulling the AIST into new fields, while the AIST pushes the frontiers of industry through innovation and the supply of students, which increase our industrial/business potential within a globally competitive environment.

It is important to note here that the AIST-Abuja campus will not be an island unto itself. It will be connected to other African universities, as well as other AISTs within Africa. As such, students and faculty from these institutions will have the opportunity to benefit from the programs at the AIST. For the students, this will include access to educational resources and research facilities, while in the case of faculty, Visiting Professorships and educational/teaching facilities will be provided to ensure that local academics have direct access to the facilities and resources of the AIST.

In addition to the interactions with the local students and faculty, the AIST-Abuja campus will be strongly influenced by the African Scientific Committee (ASC) and the International Scientific Advisory Board (ISAB). These are two independent groups that have been established to provide scientific and technological inputs to the AISTs. The ISAB consists of a group of highly accomplished international scientists and engineers. It is chaired by Prof. Phillip Griffiths of the Institute for Advanced Studies (IAS) in Princeton.

The ISAB provides scientific oversight to the Board of Trustees of the AISTs and the highest level of calibration of AIST activities. The ASC provides working inputs to the academic curriculum, research and innovation efforts within the AISTs. It is a group that includes 70 members selected from Africa and the Diaspora. The group represents 32 key fields that span the complete range between science, engineering and the humanities. It is a highly distinguished group of academics and practitioners that I am honored to chair.

The objective of the ASC is to develop the framework for the knowledge-based transformation of Africa. As such, the group is open to interaction with the AISTs, as well as interaction with other institutions. Ongoing activities of the ASC include efforts to develop curriculum and research for the AIST-Abuja campus; research collaborations with selected African universities; AIST development in other African countries, such as Burkina-Faso, Tanzania, Rwanda, Ghana, South Africa and Egypt. These are just some of the ways in which the Africans in Africa and those in the Diaspora can work together in building a platform for sustainable African development.

Concluding remarks

This article presents some ideas on the role science and technology education can play in Africa's development. Science and technology is proposed as the engine of economic growth. Within this framework, business/industry are the drivers, government is the catalytic converter and academics are the fuel. An integrated strategy is therefore proposed to link these stakeholders in the business of African development. Such strategy should include the establishment of Centers of Excellence, such as the African Institutes of Science and Technology (AIST). The other seeds that must be sown include strategies to promote the long-term growth of industries. These will require an integrated manufacturing initiative that will involve close collaboration between government, industry/business, academia and development partners. Like the "Asian Tigers", the long-term goal must be to create a new generation of "African Lions" with Africa as one of the leaders.

Wole Soboyejo is Professor of Mechanical and Aerospace Engineering, Princeton University, and Chair of the African Scientific Committee.

The help of Ms. Betty Adam in preparing this manuscript is gratefully acknowledged.
Poverty Alleviation and Economic Growth in Rwanda through S&T

BY ROMAIN MURENZI

THE RECENT HISTORY OF RWANDA which culminated in the genocide of 1994 devastated the Rwandan economy and destroyed much of the infrastructure. Tragically the loss of up to one million people left the human resource base, in particular of trained personnel, in a desperate situation.

Ten years on the new Government has succeeded in rehabilitating infrastructure, restoring public services and re-establishing a credible government in the eyes of both the people of Rwanda and the international community.

Despite the massive achievements since 1994 however, with a per capita income of approximately $60, the typical Rwandan lives below the $1 per day poverty line. Approximately 90 percent of Rwandans are engaged in subsistence agriculture and only 6 percent have access to electricity and clean water.

- National science, technology, and innovation policy and strategy

RWANDAN PRESIDENT PAUL KAGAME in a recent speech to the Royal Society in London, stated:

"We in Africa must either begin to build up our scientific and technological training capabilities or remain an impoverished appendage to the global economy.

We all know that the application of science and technology is fundamental, and indeed, indispensable in the social and economic transformation of our countries. Productive capacities in modern economies are not based merely on capital, land, and labour. They are also dependent on scientific knowledge and sustained technological advances."

A National Science, Technology and Innovation Policy Document has therefore been written to build on the immense work that has been done since 1994 to develop

Sprinkling of a tea plantation with vermin pesticide near the volcano-national park in Rwanda.
Rwanda and to enhance the Science, Technology and Research capacity, and to reinforce the development pillars of Vision 2020, within all sectors of the Rwandan economy.

The overriding objectives of this policy are as follows:

- To support the growth of the economy of Rwanda, specifically to support the Vision 2020 targets of a steady growth in GDP—8 percent per year from 2010 to 2020;
- Advance the quality of life for all the citizens of Rwanda, specifically to support the Vision 2020 target of a GDP per inhabitant of $900 by 2020;
- Improve Skills and Knowledge among the population, specifically to create a "knowledge" economy;
- Maintain viability and strategically choose to enhance opportunities for growth in rural areas;
- And integrate Technical Education with commerce, industry and the private sector in general. Specifically through: knowledge acquisition; knowledge creation; knowledge transfer; and an innovation culture.

Rwanda's development challenge, therefore, involves building the science, technology, and innovation (STI) capacity needed to acquire, adapt, and utilize existing knowledge to solve Rwanda's pressing social and economic development challenges, including such issues as:

- The inability to meet food and nutrition needs of the population at large;
- Over-explotation of land;
- The need to widen and diversify the economic base by producing a larger range of higher value added, more knowledge-intensive goods and services for the domestic market and for export;
- The need to generate a cash income for subsistence farmers. This cash income will, in turn, help to revitalize the economic and social life of village economies and provide the financial resources for sustainable social programs;
- The need to improve access to electricity and hence reduce dependence on biomass;
- The need to improve access to clean drinking water;
- The need to improve nutrition and hygiene;
- Fighting the prevalence of malaria and HIV/AIDS;
- Raising per capita income, which is currently $260/year or $0.71/day. Per capita income will have to increase by 40 percent just to reach the $1/day level;
- The need to produce low volume, high value, high quality goods and services since Rwanda has neither the location nor topography to support the production and transportation of low value, bulk commodities. This means that Rwanda must develop the capacity, which it currently lacks, to inject and ensure quality at every stage of the value chain.

Ministry in charge of Science, Technology and Scientific Research in the President's Office

IN MARCH 2006 a new Ministry in Charge of Science, Technology and Scientific Research was created, under the President's Office, in a move to strengthen the integration of science and technology in all sectors of the economy.

The new Ministry has the responsibility for the formulation, coordination, and management of national science, technology, and research (STR) policies and strategic plans for economic growth and poverty reduction. It has the accountability for the promotion and building of the national science and technology innovation system and capacity and through this to promote innovation and commercialization of scientific and technological knowledge and ideas.

An ambitious strategy for the strengthening of Science, Technology and Research across all sectors of the Rwandan economy and educational system is currently being developed with assistance from the World Bank and DFID. These measures include:

- The establishment of a legal and regulatory framework governing Science, Technology and Research;
- The establishment of a National Commission for Science, Technology and Innovation;
- The establishment of a science and technology trust fund to enable Rwanda's best performing students in science to study science and technology at top level institutions internationally;
- The establishment of research fellowships to enable our highly qualified scientists to engage in high level research;
- Industrial attachments in all major projects, (agriculture, water and sanitation, transport, industrial, energy);
- Specific Research in commodities with potential for economic growth;
- The establishment and reinforcement of high quality laboratories and associated research to ensure sanitary and phytosanitary standards are met;
- The establishment of laboratories in all health districts and a state of the art reference laboratory;
- The establishment of Centres of Excellence in areas which are of particular importance to Rwanda, these will include: biodiversity, appropriate technology/alternative energy, Geographic Information Systems;
- Review of the potential for the development of bio-fuels in Rwanda; and
- Reinforcement of the capacity of industries to conduct...
research in their area of specialization with a view to support the growth of these industries. I would like to stress a few examples of our planned interventions in the above:

"Beer is chemistry"

As I mentioned above, one of our plans is to reinforce the capacity of industries to conduct their own research with a view to support the growth of these industries. One example of our major industries is BRALIRWA which for years has been the sole producer of beer in Rwanda. The importance of both scientific education and research cannot be overemphasized when one considers the chemical input and nature of the manufacturing process of the beer. Ways of developing both quality and range of products will be greatly enhanced by the skills development and capability of our research scientists in support of this process.

“A cow is a teacher and an agent of technology transfer/diffusion”

I refer to one of the schemes being operated by the Rwandan Government for injecting sustainable wealth and income generation into the rural communities through the spread of technical knowledge. This entails the provision of either a pure hybrid cow or a local Rwandan long horned cow to families that meet certain criteria for being able to maintain them. The condition attached is for the families to pass the first female offspring of the cows to neighbors, (second female offspring in the case of the local breed) with a government target of 600,000 cows in families in the next ten years.

Part of the package in advance of receipt of the cow is training on the products and by-products of the cow including milk and milk processing, meat, manure from the cow dung, energy produced from the cow dung, and similar areas of technical knowledge. This is a major educational exercise for the rural farmer and hence the "cow is a teacher and an agent of technology transfer/diffusion."

“Bringing cell phones to rural villages is like introducing a positive charge into a quantum vacuum”

One of the main drives for the Government is in the development of National Communications Infrastructure through their NICI plan process. Already the national mobile phone network has surpassed 300,000 users, from a start of only a few thousand fixed land lines less than ten years ago when mobile telephony was first introduced in Rwanda. To date there has been only one operator in Rwanda and with the advent of competition in the mobile telephony market this is now set to increase exponentially the spread of both mobile telephony and associated broadband internet infrastructure throughout Rwanda.

With up to 90 percent of Rwandans still living in rural villages this is set to again create a major impact on their lives.

The target is to both introduce low cost phones, with a manufacturing plant in Rwanda, together with schemes to assist in the purchase of the phones.

The use of mobile phones will support literacy through the use of SMS, mobility and empowerment of the people through communication, and enhanced services such as mobile banking, and hence with such powerful effects "Bringing cell phones to rural villages is like introducing a positive charge into a quantum vacuum."

Other Science and Technology initiatives

The above represents only a small snapshot of the many interventions the Government of Rwanda, through the new Science and Technology Ministry, intends to introduce in the country. Examples of some of the initiatives include the following:
- **Agricultural productivity.** Using new (to Rwanda) cultivation methods and input packages to boost agricultural productivity of subsistence farmers.
- **Alternative energy.** As most Rwandans live in villages that are not connected to the power grid the intention is for the introduction of small distributed local generation schemes using micro-hydro, solar, bio-mass, wind, etc to provide energy to rural communities.
- **Water conservation and rain water harvesting.** Water borne diseases, caused by a shortage of potable water, are a major source of illness in Rwanda, hence the need to introduce simple rain water harvesting/conservation techniques and schemes in villages, coupled with water purification systems.
- **Food processing and food storage.** Increasing agricultural yields will not improve food security if food cannot be safely processed and stored.
- **Public Health.** Health education needs to be widely available to help educate the rural population in areas such as nutrition, sanitation, hygiene, disease prevention, and, as mentioned earlier, the importance of clean, safe drinking water. Public health extension agents and medical technicians need to be trained, deployed in villages, and connected to regional health centers via the Internet. All this will entail targeted STI capacity building.
- **Technical and Vocational Education.** Rwanda suffers from a major shortage of skilled technicians and craftsmen needed to perform such diverse tasks as repair automobiles, repair and maintain electrical appliances and such electronic equipment as printers and copiers, and craftsmen who can design and construct needed facilities like rainwater harvesting systems and schools.

Romain Murenzi is Minister of Science, Technology, and Scientific Research of Rwanda.

1 The full text for President Kagame’s speech is available at:
- http://www.scidev.net/pdf/pdffiles/President-Kagame-speech-Sept06.pdf
Commercialization of Science
A key landmark for an efficient National Innovation System

BY PETER LINDHOLM

"ONE OF THE MAJOR limitations to the commercialization of research activities in Tunisia is the absence of a clear strategy that indicates which technologies can be commercialized and how," told Ahmed Rabiei of the Centre of Biotechnology of Sfax, Tunisia, to SciDev.Net.

This phrase, uttered last September, gives a good clue of the challenges faced by policy-makers in general and more specifically in emerging economies when dealing with their ambition to develop a knowledge-based economy.

This article starts with a concrete example and expands to include lessons learnt for policy-makers and practitioners. The outlined process (doing, testing, developing a strategy and a policy) is based on a true story, a project my team has implemented during the late '90s in the Region of Mecklenburg-Pomerania, Germany, just a few years after the fall of the "Wall." In my view it is an interesting case as it helps understanding of how pragmatic testing can meet more ambitious policy visions. It is a success story because it created wealth for the region, additional off-budget resources for scientists as well as their institutes, and participated in rejuvenating the image of this area.

It must be recognized—without taking credit away from the local scientific community—that Rostock (the main town) and its surroundings were not really on the mind map of specialists thinking about scientific excellence around the world. What is remarkable is that in just a few years this community, with the help of the Federal Government, was able to design and implement an innovative system
(Innovation System) that boosts the local economy, increases scientific excellence and presents a solid return-on-investment of public spending in science and technologies.

The ingredients at the starting point were:
- Limited scientific excellence;
- Nine R&D institutions bringing together circa 3,000 scientists working in their own sphere of competencies (in other words, "nothing special");
- A local government that was willing to develop a policy in which science and commercialization of science became a building block for the future;
- An emerging opportunity thanks to a new national initiative helping pilot regions to test innovative ways for commercialization of science.

The economic background was pretty bad. After the collapse of the Wall, this part of former Eastern Germany was facing (and still faces to some extent) a terrible economic crisis, including the collapse of its industrial sectors, a high level of unemployment, an aging population with problems of qualifications, and more.

The goals of the authorities were classical policy goals: a) create highly qualified jobs; b) increase tax income; c) create technology-based companies; d) attract inward investors; and e) develop a positive image of the area.

The success story of Mecklenburg-Pomerania is based on a mix of interrelated ingredients. But the main element that helped address the issues of this complex environment was bringing the community together and agreeing that commercialization of science should be tackled through a public-private-partnership joint-venture that would become viable for results. These two elements—PPP and liability—are the cornerstones that facilitated the "breaking the mould" process between scientific and political institutions.

The procedure used to enter into this PPP is described below. This course of development was carried in five steps: a) creating a consensus; b) understanding the potential; c) mobilizing the scientific community; d) recruiting highly qualified staff; and e) being demand driven.

During nearly nine months the management team had been contacting all stakeholders to convince them that creating value out of public research was a theme that implied other means and ingredients than classical commercialization offices were pursuing for so many years. Our team had some clear ideas about what these new ways could look like. At the same time it was obvious (we had been struggling in other places in the world and had learnt our lessons) that vice-chancellors, scientists, heads of institutions, public authorities, and the business community had to be able—and willing—to go in the same direction and share some of their resources and responsibilities. So these nine months gave birth to a consensus and this was turned into a formal agreement based on some apparently simple principles:
- Making value out of knowledge and/or technologies implies that a team of professionals takes care of this activity;
- These professionals need to be tuned towards the understanding of the demand from buyers;
- Commercialization of science is understood in its broadest meaning, i.e.: any activity that generates value. This includes outsourcing of research, finding international financing for R&D, selling IPR, creating technology-based start-up companies, and the like;
- This team should not be driven by scientists. Their job is in their labs;
- The implementation will be driven by clear targets to be achieved but will be granted with medium-long term financing;
- To be able to bring together a "good commercial" team that could receive rewarding revenues, it was essential they could be dealing with a "critical mass" of scientists that was large enough to ensure that a deal flow of scientific goods were available for the market(s).

The result of these activities were the creation of a public-private-partnership between the commercialization team, the nine R&D institutions, and the local government, and an agreement that the commercialization team would benefit from a right of first refusal for innovations that spun out of the labs.

The second issue—understanding the potential—was addressed in a down to earth way. This was perhaps in response to Mr. Rabie’s questioning: each team in each lab has something that might respond to the needs and financial capabilities of someone, somewhere. In other words the issue was, and still is, to invest enough resources to analyze the potential embedded into the competencies of the scientists working in these laboratories and search on an iterative basis if these competencies have a value for companies or other institutions. Again, to be very pragmatic, the commercialization team did not focus on apparent scientific excellence. It focused on R&D teams that were willing and able to enter into negotiations with "buyers".

This seems trivial, but it is, de facto, one of the keys to success: unless there is a piece of technology ready to be sold in its existing status (a very rare occurrence) the achievement of a commercial deal between a company and a group of scientists highly depends upon the capacity of the these two partners to trade together. This implies time, efforts to close the cultural barriers, and willingness to make some compromises (for companies, paying the right price and waiting: for scien-
tists, accepting that the best piece of knowledge is not the aim of the company that is looking for something that can be used as soon as possible for a reasonable price.

The result after over a year of operation was a sort of natural distinction between three circles of scientists: those who were willing and able, those who were hesitating and those who did not want. The commercialization team focused its efforts on Circle One, ensured that a good, ongoing communication campaign was delivered to Circle Two and ignored Circle Three.

Outputs are easy to measure. After the second year of operation, the commercialization team was able to generate a direct income of approximately 50,000,000 euros par annum (all inclusive: R&D contracts, royalties, start-ups, joint-ventures, access to international funding) for a cost of less than a million. The members of the PPP (especially the heads of the nine R&D institutions) receive additional off-budget resources, individual scientists enjoy a better income, and the public authorities are happy to see economic development, change of image, and the establishment of a network of young technology-based firms that nurture the future of the region.

Are these good results, or are they modest compared to what is invested in public science? An honest response is probably to say both are true. 50 million euros is negligible compared to the potential. 50 million euros is several times more than before and has a very strong positive impact on the local entrepreneurial culture.

Finally, to end with this case, a few words about the demand side. In a way this was THE surprising factor. Again, the geographical area is not so well known for breaking the limits of knowledge. But what buyers, partners, and other R&D institutions were willing to find was different. These organizations were able to provide good R&D teams, ready to work hard, addressing their needs on the basis of an ongoing dialog. The commercialization team played a paramount role and "presented itself" as the honest broker in this process. Firms, including large and prestigious ones were ready to allocate resources on a recurrent basis to loyal, reliable teams coached by an intermediary that took care of all the needed features before, during and after the transactions are made.

Finding these potential clients implies having an open eye on many different markets. In turn, this obliges the commercialization team and scientists to brainstorm on who could be the best user of some competencies, pieces of knowledge, or technologies. As time goes by, the addition of data and practice helps in detecting and selecting the most promising and profitable markets. This activity is a full time job for more than one individual and necessitates bringing together commercialization staff from different countries with different networks and cultures.

Trying to create a return-on-investment from public spending in science is a wonderful and exciting job. After years of operations we learned a few simple things that I propose to summarize as follows:

- Learn about humility. There is no one magic solution. Copying and pasting from elsewhere simply does not work. Each commercialization of a science program is a new adventure that needs to be tailor-made for the locals.
- Humility and pragmatism do not prevent that some ingredients need to be brought together. This includes public seed financing, the ability to stimulate demands from buyers, the capacity to understand and mobilize individual scientists, the need to create a consensus with heads of R&D institutions and the absolute necessity to allocate commercialization work to highly skilled staff.
- And a good deal of luck....

The next question we want to address is about policy-making. Using the lesson learnt, what could be extracted for policy-makers that intend to invest public funding creating or favouring the development of a knowledge-based economy in their countries?

To make it short, we propose a four-step approach based on a number of experiments:

1. Proactive thinking and looking at others.
2. Deciding.
3. Implementing and
Looks simple, but it is not. Each step implies continuity, courage, financing, and expertise.

1. Proactive thinking and benchmarking
This is about sending a clear message to the business community, scientists, heads of R&D institutions, and other players around the world, showing the country is determined to use its "brains" for future growth. In other words, it is not only about laws, foresight, and finances; it is a new paradigm for all those who can use knowledge and technology to create additional value. This message is not trivial because science is not often considered as classical budgetary spending and for which return-on-investment is difficult to predict. The result is that policies sometimes do not take into account that taxpayers' money must generate wealth as well as new knowledge.

To bridge the future competitiveness of the country and investments in the scientific sector, policy-makers must allocate significant time to review what they can really invest in, avoid over-optimistic visionary statement (e.g.: the year 2000 Lisbon Agenda. The heads of States and the European Commission decided that thanks to a R&D investment as high as 3 percent of its GDP, the Union would become the most competitive area in the world by 2010. The reality check is a bit brutal). It is about consensus building, looking at unique selling points, making ventures with other areas, accepting that time is a key ingredient in this matter and that the policy will have to be sustained over years... and elections.

Altogether it is a process and this process is multidisciplinary. When possible, we tend to recommend keeping this subject at the highest political level in order to maintain the capacity to go beyond the interest of a Ministry of Science, a Ministry of Finance or of Industry.

2. Deciding
Decision-making is both complex and easy from the point of view of policy-makers. The issue, when it comes to establishing a National Innovation System, is about being sure that stakeholders of today, and tomorrow, will endorse the policy and continue to pursue the vision that sustains it. A good starting point is to establish pilot projects that bring together scientists, heads of institutes, lawmakers, civil servants, business and financial people, and higher education using findings to fine-tune the policy.

3. Implementing
Policy is defined, the strategic aspects are prepared. What is key now? People and only people. Successes and failures of commercialization programs are nearly always based on the lack of staff able to understand the needs of users (entrepreneurs) and the capacities of the scientific system. Often Commercialization Centers are handed-over to scientists or heads of R&D institutions. This rarely works.3

Policy-makers must ensure that the teams in charge of stimulating the demand side as well as the offer from scientific teams do understand all communities involved (including international markets). These teams must be made liable for results and their salaries (this can include success fees) must reflect this risk.

4. Monitoring
Monitoring systems often stay at the level of intentions. This is a mistake as only a solid, transparent and well-designed monitoring system helps the different players adapt the National Innovation System to realities, keeping in mind the overall objectives of the policy.

To close the loop, Mr. Ahmed Rabei in Sfax, is right: It is difficult. What would be wrong is not to try, fail and try again....

Peter Lindholm specializes in the design of Innovation Policies, National Innovation Systems and the implementation of commercialization of science programs. He can be reached at peter.lindholm@wanadoo.fr.

Endnotes
1 Initial financing came from the federal government after a tender procedure launched to test new ways to address commercialization of science. Local financing quickly came and match-funded the program.
2 Results presented by an external, independent Auditor appointed by the Federal Government.
3 As proven by the IITE project of the European Commission that analyzed the performance of over 500 commercialization teams across Europe.
Latecomer Strategies for Catching Up

Linkage, leverage, and learning

BY JOHN A. MATHEWS

The foundations of successful development lie in the formulation of latecomer strategies which enable countries that arrive late on the world industrial scene to accelerate their development through targeted catch-up efforts. The latecomer advantage needs to be captured by developing countries through targeted strategies. The potential advantage consists of this: a country arriving late on the industrial scene is able to access advanced technologies that have been developed elsewhere and put them to business use at lower cost than advanced firms themselves—sometimes at lower cost, and faster, than the very firms that developed the technologies in the first place.

To secure such an advantage firms need to be able to identify which technologies are relevant, and then secure access to them, and do so fast—so that a business can be built around such advanced technologies, utilizing advanced management, with low costs or other advantages that a latecomer developing
country can marshal, so that market opportunities not yet captured may be seized.¹

This is a 21st-century version of the latecomer strategies that worked well and allowed countries such as Germany and the US to catch up with the industrial leader in the 19th century, Great Britain. Japan, followed by the East Asian Tiger economies of Korea, Taiwan, and Singapore, applied these strategies in the 20th century. Now in the 21st century we see the cases of China, India and Brazil leading the developing world in the capture of latecomer advantages. According to the classic concept of latecomer development fashioned by Gerschenkron (1962), the key has been the development of "special institutions" that accelerate and facilitate the catch up process—such as the Deutsche Bank in Germany in the 19th century; or the Ministry of International Trade and Industry (MITI) in Japan and the Industrial Technology Research Institute (ITRI) in Taiwan in the 20th century; or the Ministry of Non-Convention Energy Sources in India in the 21st century.

Strategies

**Strategies Have a Goal**, or purpose—and the principal purpose of development is to close the gap between the advanced and what Gerschenkron called the "backward" countries. The situation facing countries and firms that arrive late on the industrial scene is one which combines apparently hopeless drawbacks, difficulties and inadequacies, with advantages that flow precisely from being "late" and not having to go through all the previous steps that incumbents have had to endure. It is convenient to call firms in this position "latecomers"—extending the usage introduced by the Russian social scientist Alexander Gerschenkron.²

Latecomer firms, like latecomer nations, are able to exploit their late arrival to tap into advanced technologies, rather than having to replicate the entire previous technological trajectory. They can accelerate their uptake and learning efforts utilizing various forms of collaborative processes and state agencies to assist with the process, bypassing some of the organizational inertia that holds back their more established competitors. They thus strategize around the possibilities inherent in their latecomer status. The strategic goal of the latecomer is clear: it is to catch up with the advanced firms, and to move as quickly as possible from imitation to innovation. The notion of latecomer firm is couched in general terms, but it can be seen to include examples of firms from East Asia, as well as examples from other developing countries, present and future.

In the context of globalization, latecomer firms are faced with new opportunities for linking up with emergent institutions and networks. Global value chains, for example, are being formed by leading firms in the advanced countries as they seek to cut costs and enhance flexibility through outsourcing. This creates opportunities for latecomers, to link up with these global value chains as suppliers.³ The more the global economy becomes interconnected, the more possibilities there are for such linkage. And through linkage the latecomer firm can secure more than just a stream of revenue. It can tap its links with more advanced firms to acquire knowledge, technology, and market access—things that would otherwise be beyond the firm’s limited resources. It is this capacity to secure more from a relationship than the firm puts in, that we call leverage. These sequences of linkage and leverage can be repeated over and over again, until a firm, or collection of firms within an industry, enhance their capabilities and become, potentially, advanced players themselves. The sustained and repeated practice of these strategies by groups of firms can be described as a form of industrial learning. Development can thus be characterized as a process of strategizing by latecomers, through the steps of linkage, leverage and learning. This involves a process of collective entrepreneurship where opportunities for such linkage, leverage and learning may be identified, seized and put into effect.⁴

Innovation in such a perspective is to be given a broad interpretation, covering not just the development of products and processes new to the world, but the adoption and adaptation of products and processes that are already in use in the advanced countries. It is this aspect of innovation that is of critical relevance to developing countries, and which was utilized to great effect by, for example, Taiwan in the creation and building of its electronics industry, or is being utilized today by Brazil in the creation of a biofuels industry. The institutional innovations involved are all concerned with the capture of technologies in timely fashion; the building of capabilities in these technologies, such as in government-owned R&D institutes; and the diffusion of these capabilities as rapidly as possible to the private sector, e.g. through a sequence of targeted R&D consortia. In view of these considerations, I suggest that it might be more accurate to refer to the system of institutions and policies not so much as a national system of innovation as a national system of economic learning—and the process involved, as one not of innovation but as the management of technological diffusion, or technology diffusion management.
State-sponsored R&D

**LATECOMER COUNTRIES** today need some kind of Gerschenkronian “compensating institution” to bridge the gap between the technological resources of the developed world and the aspirations to catch-up on the part of the developing world. Let us call such a prime institution a DC-ITRI, where the Taiwanese Industrial Technology Research Institute (ITRI) provides a suitable model. The DC-ITRI would be a prime agency in building pilot versions of new technologies before they are taken up by the private sector in the developing country. The DC-ITRI would not be engaging in fundamental scientific research. On the contrary, it would be concerned strictly with identifying and evaluating available technologies. It would provide shared R&D services for existing and emerging industries in the developing country. This is precisely what the R&D Department of a large, established company performs. Technologies already being used are subject to testing to see how they can be improved; technologies used by rivals and competitors are constructed and analyzed; potential technologies that could substitute for the ones in use are being evaluated. These are all the activities carried on in the R&D Department of a large firm like IBM or Toshiba or Samsung. But in a small developing economy, few firms can afford such a Department. If they can, then they can make the technical evaluations of new projects for themselves—or they can hire expensive consultants to do it for them. But most firms do not have the means to benefit from such services. The DC-ITRI would provide the general institution that fills this gap, in that it can be seen as an institution that can accelerate the country’s creation of national absorptive capacity in one field of technology, and hence one business field, after another. Thus the DC-ITRI would provide a way of raising the absorptive capacity of industry as a shared service available to many firms.

If the institution is successful and helps industry to be upgraded and stay abreast of the world technological frontier, then there would come a time when it could be dismantled, or privatized. But that time is probably far off—given the existence of such public R&D technology capture institutions in countries such as South Africa (the CSIR) or Australia (the CSIRO) or Hong Kong (ASTRI) not to mention the continued existence of ITRI in Taiwan and the network of R&D institutions in Singapore assembled under the umbrella of A*STAR.5

**Renewable energy technologies**

Let us now turn to a specific technological area where many tropical countries, starting at a low technological base, can expect to make considerable headway in future years—namely in the area of renewable energy technologies, such as in production of biofuels or in decentralized biomass gasifiers producing electric power. The case for a tropical developing country to seek an industrial development strategy based on renewable energies is economically rational, and lends itself to a latecomer strategy of technological catch-up. Until recently, it was the conventional wisdom that renewable energies would be a marginal and costly alternative to fossil fuels, that might make some headway over a century or more as technologies improved. But the cases of Brazil and China and India shows that renewables—led by biofuels and in particular ethanol—are competitive here and now, and what’s more represent an exceedingly attractive option for developing countries.

The advantages for developing countries of building up renewable energy systems over their fossil fuel counterparts as transport fuels or as sources for electric power produced in large-central power stations are many, and include the facts that such sources are cheaper than oil-based conventional systems; they provide energy security as opposed to dependence on imports from unstable oil regimes; they burn more cleanly than fossil fuels; they generate fewer greenhouse gases; they promote rural development and enhance life opportunities in rural areas; they can generate new export industries for developing countries; and even countries with a low level of science and technology can get a start with biofuels.6

Brazil is demonstrating how this can be done, through its ethanol program involving sugar cane, and now its biodiesel program involving vegetable oil seeds such as castor and soybean crops. In the words of the country’s president, Luiz Inacio Lula da Silva (‘Lula’) this program had by July 2006 already generated 100,000 new jobs in growing soybeans and other oil crops in the NorthEast of Brazil. The president made the claim that the biodiesel program has been designed as much with social goals as with fuel supply goals.7 The point is that a country in Africa can emulate this example, and devote large tracts of land otherwise unsuitable for food crops to fuel crop production. Domestic consumption can provide an initial market, since the fuel produced can displace expensive oil imports. As sophistication is acquired, and export markets are opened up, so the agricultural practices can be improved, and advanced distillation systems installed, and technological know-how in the country can be enhanced. This will then have spillover effects in other sectors.

India too is demonstrating such a strategic approach, both in production of biodiesel (such as from the wonder oilseed produced by *Jatropha curcus*) and ethanol from sugar cane, and in rural biomass gasifier-based decentralized electric power production. India now has several examples of such village-based biomass gasifier schemes for decentralized electrification, which present an example of sophisticated technological uptake that can be emulated throughout the developing world. Such village-based systems are a genuine alternative to large centralized systems, and potentially can be grid-connected to promote grid reliability.

The DC-ITRI discussed above would play a crucial role in such developments. No developing country could be expected to make large-scale investments in ethanol distillation plants or other biofuels or renewable energy systems such as biomass gasifiers without establishing the technical options in the first instance and then building prototypes to check their feasibility in the country concerned. The wastes from ethanol production, termed vinasse, might have quite different properties in a tropical country as opposed to a temperate country where prior research might have been conducted, and the same
applies to biomass gasification. The DC-ITRI would play a critical role in piloting the country's linkage with advanced knowledge institutions and leveraging skills from them, in an iterated process of technological learning.8

As a renewable energy industry becomes established, so it promises to drive industrial development through industrial linkages and complementarities. The renewable energies sector promises to play the role of a critical 'development bloc' for Brazil, India and China in the first instance, and for a wider swathe of developing countries through the tropics more generally. The category of development bloc was introduced and defined by the Swedish development economist, Erik Dahmén in 1950, based on his studies of entrepreneurship in the Swedish economy.9 He defined it as "sequences of complementarities which by way of a series of structural tensions, i.e. disequilibria, may result in a balanced situation" (1989: 111).10 Thus a development bloc represents the systemic counterpart to the consideration of market demand as well as supplier competence in the microdynamics of technological trajectories. It generates the forward and backward linkages that can drive industrial development.

So, the developing countries have everything to gain from promoting biofuels and renewable energies of various kinds, such as biomass gasifiers, and nothing to lose. They will not be sacrificing other options to do so, because they do not have other options in place—other than underdeveloped fossil fuel utilizing systems that are becoming prohibitively expensive and economically crippling as oil supplies peak. They will not be sacrificing resources such as land because they have land in excess supply, particularly the kind of degraded land that is best utilized for fuel crops such as sugar cane or Jatropha. They will be saving themselves from the trap of being dependent on oil imports at a time when the price of oil is rising inexorably, and security of supplies is anything but certain. They will be contributing to promoting cleaner air in their cities and reducing greenhouse gas emissions overall—for which carbon credits should become available soon under a Kyoto-like process. There is every reason for developing countries, and for agencies such as the World Bank, to move ahead in supporting catch-up strategies for development generally, and with a focus particularly on biofuels and renewable energies in tropical countries.

John A. Mathews is Professor of Strategic Management, Macquarie Graduate School of Management, Macquarie University, Sydney, Australia.

References


Endnotes
1 For some successful cases, see the World Bank report, Technology, Adaptation, Exports: How Some Developing Countries Got It Right (Chandra 2006); the cases covered span India, China, Malaysia, Chile, Kenya, and Taiwan.

2 See Gerschenkron 1962. For the application of the concept of latecomer to firms, see Hobday 1995; 2003; and Mathews 2002; 2005; 2006.


4 See the UNIDO report Industrial Development 2002/03 for an application of these ideas.

5 On these technology capability-enhancing institutions, see for example Lall 1997; and Lall and Pietrobelli 2003, as examples from a large literature.


7 ‘We need each other’: Why Lula is backing a Latin axis but will shun the populist path, by Richard Lapper and Jonathan Wheatley, Financial Times, July 12 2006, p. 9.

8 In India, the biomass gasifier projects have been led by public R&D institutions, such as the Centre for Sustainable Technologies (CST), Indian Institute of Science, at Bangalore. For an example of CST’s work with gasifiers, see the paper by Ravindranath et al (2004).


10 Carlsson and Eliasson (2003) have taken up the concept of development bloc and renamed it competence bloc—to emphasize that such a collective capability is needed to support and sustain technological innovation. If the technological system represents the supply side of industrial dynamics, then the development bloc or competence bloc represents the demand side. Both are necessary in the business of seeding and growing industries in developing countries.
First-Rate Science and Modernization of the National Research System in Chile

BY CLAUDIO WERNLI

IMPLEMENTATION OF the Millennium Science Initiative (MSI) Program, since its inception seven years ago, has been successful and exemplary. The achievements of the Millennium Science Institutes and Nuclei can be gauged from the significant number of young scientists they have trained and from their success in attaining and promoting excellence in scientific research, in fields as varied as biology, biotechnology, physics, glaciology, computer science, engineering, ecology, mathematics, geophysics, and chemistry, with links to both the private and public sectors and education, thereby making a substantial contribution to key areas of national development. Their work has also helped trigger a number of well-planned cooperative and interactive initiatives within the national scientific community.

In Chile, as the 2002 Report on the Chile-World Bank MSI Agreement points out, the Millennium Science Initiative constitutes a successful illustration of a better and economically effective approach to scientific research, thereby helping to strengthen Chile’s National System of Science, Technology, and Innovation. Over the past decade, the Government has quadrupled the resources it has allocated to that System, underscoring with concrete measures and actions the importance it attaches to scientific and technological innovation for Chile’s development.

Thus, the high level of acceptance and enthusiasm sparked by the MSI in the science and technology community has created a propitious environment for increased investment in the sector. The fact that the MSI has been taken as a model for other countries shows that the international scientific community also acknowledges this Program’s innovative features. In 2001, it was already being applied in Venezuela, Mexico, and Brazil. In 2004, Kenya adopted it,
along with a small network of African countries, and over the past two years concrete steps have been taken to introduce it in Vietnam and Kazakhstan. Interest in implementing the MSI has also emerged in China and Bangladesh.

Original competitive funding

SINCE ITS ESTABLISHMENT in July 1999, based on an agreement between the Republic of Chile and the World Bank under which the Bank granted a Learning and Innovation Loan for implementation of the Initiative, the MSI has been characterized by a series of original features with respect to competitive funding for science, technology, and innovation. It operates like a competitive, public, and transparent fund, in which project proposals are evaluated and selected by a jury of eight distinguished foreign scientists representing different branches of knowledge and geographical regions, aided by specialists. Funds are disbursed directly to research teams. The MSI uses a new competitive selection process whereby applicants are asked to submit a project outline and only those who are short-listed are required to present a complete project. Those awarded a grant also have to meet certain basic conditions: for instance, that they engage in cutting edge research; train young scientists; collaborate and work via networks with other centers of excellence in the region and in other parts of the world; and share their progress with the rest of the world, especially the educational sector, industry, services, and society at large.

The MSI Program has become one of Chile’s most promising sources of competitive funding and one that has endeared itself to the nation’s academic and scientific institutions by being sensitive to those institutions’ objectives and approaches. In so doing, it has helped strengthen them, contributing to state-of-the-art scientific and technological research: a vital lever for any country’s economic, social, intellectual, and cultural progress. Thus, from its inception, the MSI has been perfectly in sync with the national developmental expectations fostered by the past two governments, in science, technology, and innovation.

Although the MSI has only a relatively small share—averaging 6.5 million dollars a year—of the approximately 560 million dollars, or 0.7 percent of GDP, that Chile allocates to research and development, that share constitutes a major investment, especially considering that the Program was initiated with a 5 million dollar World Bank grant, with an additional 10 million dollars in national counterpart funds, for a three-year period, and that in 2006 the MSI has an entirely domestic budget of close to 8.5 million dollars.

It is worth pointing out that 94 percent of the MSI’s operating budget goes directly into research, with only the remaining 6 percent being used to cover management expenses. Of those 6 percentage points, only 3.5 correspond to the expenses of the Executive Secretariat, which is responsible for implementation and operation of the MSI’s scientific, administrative, and financial affairs.

The research and development contributions made by the MSI Centers undoubtedly advance the goal set by then President Lagos, and ratified by the current President of Chile, Michelle Bachelet, of doubling the share of GDP devoted to these items by 2010.

More and better

THE MSI CURRENTLY CONSISTS of three institutes and 14 science nuclei, all of which are formed by a high proportion of Chile’s best and most internationally renowned scientists, eight of whom have won National Science Awards, while three are members of the United States Academy of Science (out of the five such members in Chile), and 12 are members of the Chilean Academy of Science; all of which testifies to the well-established qualifications of the teams and researchers that make up our Centers of Excellence.

Sustained progress has been made in developing a critical mass, especially if one considers that when the Program began few people predicted that it would grow so swiftly and with such high quality human resources. Together, the five tenders for Millennium Science Nuclei (1999, 2001, 2002, 2004, 2006) and the two tenders for Millennium Science Institutes (1999, 2005) elicited over 300 bids that met the bidding conditions: a record for a country like ours in which scientific research is better known for its quality, rather than quantity.

Cutting-edge research

THE RESEARCHERS WHO RUN the MSI Centers agree that this Initiative affords a real opportunity to engage in first class science, as well as stability and basic resources for research. Dr. Mary T. Kalin, Director of the Institute of Ecology and Biodiversity -IEB, has emphasized in several interviews that "the MSI Centers must be construed as an umbrella for enriching and enhancing existing lines of research and conducting cross-cutting research, in order to assist young scientists and ensure that knowledge is passed on to the public."
Comments such as these confirm the enormous progress made by the MSI Centers in terms of the international impact they have had in various fields of cutting-edge scientific research. Some of these achievements are well known: in molecular genetics; in subjects related to the conservation of ecological biodiversity in indigenous forests and forests with imported species; in ice field research and astrophysics; in studies of the nervous system and of the workings of the brain; and in studies of the properties of materials used in state-of-the-art technologies, such as laser. Notable progress and discoveries have also been made in information mathematics, bioengineering, industrial optimization systems, information and communication technologies, and vegetal cell biology, as well as other fields of research.

**Source of training**

TRAINING YOUNG SCIENTISTS is one of the core functions performed by the Millennium Institutes and Nuclei. From their inception, all of them have set about this task with great enthusiasm and success: a key achievement at a time when Chile’s scientific community needs the contributions of a new generation. Between 2000 and 2005, the MSI has helped train over 400 young researchers in different fields, including several graduates. Of the total, 45 percent are doctoral students. The success of the MSI Centers in this respect has been acknowledged by the World Bank, which considers them "by far the most important source of advanced scientific training in Chile."

![Figure 2: Participation in the Formation of Young Researchers Per Associated Researcher in the Period 1991-1999 and 2000-2002/3](image)

**Links with impact**

**THE ACHIEVEMENTS OF the Millennium Institutes and Nuclei** have an enormous impact on the outside world, particularly as there are direct ties with the private, public, and education sectors.

With respect to the work of MSI Centers in connection with strategic branches of industry, the projects conducted jointly with the mining, forestry, banking, health, and environmental sectors have had a particularly strong impact. As for the

---

**MILLENIUM INSTITUTES AND NUCLEI**
The Millennium Science Institutes and Nuclei are centers combining science, technology, and engineering to make a valuable contribution to the advancement of key areas of national development.

**INSTITUTES**

- Millennium Institute for Fundamental and Applied Biology—(MIFAB) [www.mifab.cl](http://www.mifab.cl)
- Centro de Estudios Científicos (CECS)—[www.cecs.cl](http://www.cecs.cl)
- Institute of Ecology and Biodiversity (IEB)—[www.ieb-chile.cl](http://www.ieb-chile.cl)

**NUCLEI**

- Center for Web Research (CWR)—[www.cwr.cl](http://www.cwr.cl)
- Millennium Science Nucleus of Seismotectonics and Seismic Hazard—[www.peligrosismo.cl](http://www.peligrosismo.cl)
- Center for Integrative Neuroscience (CENI)—[www.ceni.cl](http://www.ceni.cl)
- Forest Ecosystem Services to Aquatic System Under Climatic Fluctuations (FORECOS)—[www.forecos.net](http://www.forecos.net)
- Microbial Ecology and Environmental Microbiology and Biotechnology (EMBA)—[www.nucleomilenio-embab.cl](http://www.nucleomilenio-embab.cl)
- Millennium Nucleus on Immunology and Immunotherapy—[www.nmii.cl](http://www.nmii.cl)
- Information and Randomness: Fundamentals and Applications—[www.dim.uchile.cl/](http://www.dim.uchile.cl/)
- Millennium Nucleus in Plant Cell Biology (PCB)—[www.pcb.cl](http://www.pcb.cl)
- Millennium Science Nucleus of Quasic Applied Mechanics and Computational Chemistry—[www.nucleomilenioquasica.cl](http://www.nucleomilenioquasica.cl)
- Industrial Electronic and Mechatronics—[www.neim.utfsm.cl](http://www.neim.utfsm.cl)
- Condensed Matter Physics—[www.nucleo-milenio.cl](http://www.nucleo-milenio.cl)
- Complex Engineering Systems—[www.sistemasdeingenieria.cl](http://www.sistemasdeingenieria.cl)
MSI Centers' work with the public sector, cooperation abounds in sectors as crucial for national development as energy, planning, fisheries, public works, health, the legislature, and the preservation of Chile's ecological heritage.

As regards its education-related activities, one of the goals of the Millennium Science Initiative is to make its findings available to the educational sector. With that in mind, the MSI Centers have contributed above all to the exact and natural sciences and to training in those fields through seminars, workshops, courses, and other initiatives.

External evaluations

PERIODICALLY, the MSI Program has been evaluated by independent panels of foreign experts, who have called it successful and exemplary. In general, these bodies emphasize the fact that the MSI has commendably carried out programs fostering excellence in scientific research and generating sound and novel forms of cooperation and collaboration in the scientific community. According to the scientists on these panels, the MSI is a focal point attracting, integrating, and promoting some of the most talented young scientists in the country.

They also affirm that, in general terms, the MSI Centers provide an environment that fosters the development of young scientists—in line with the objective of increasing the size and integration of the Chilean scientific community and ensuring

that it retains its members; enables researchers with shared interests to attain a critical mass; and yields additional benefits in terms of shared and efficiently utilized resources.

The external evaluations also agree that MSI Centers achieve a high level of productivity, particularly in new fields. Their publications are deemed not just plentiful, but of high quality, too.

Both the independent panels and the MSI's Program Committee insist that most of the teams have dealt successfully with the challenges posed by an extension work component, in the sense of establishing contacts and interacting with industry, the private sector, and society as a whole.

The MSI's successful support of training and innovation was a key factor in the World Bank's decision to support training and innovation in Chile. In 2003, an important agreement was signed by the Government of Chile and the Bank, through the National Committee of Scientific and Technological Research (CONICYT) "Science for the Knowledge Economy Project" or "Bicentennial Science and Technology Project (PBCT)". The PBCT finances scientific and technological research initiatives and, at the same time, supports the Government of Chile's strategy of establishing a comprehensive approach encompassing scientific training and technological innovation.

Claudio Wernli is Executive Director of the Millennium Science Initiative in Chile.
Scaling Up Innovation
The GoForward Plan to Prosperity

BY THOMAS D. NASTAS

INNOVATION, SMALL AND MEDIUM enterprises (SMEs), entrepreneurship and venture capital (VC) are ingredients in the creation of knowledge based economies; witness the success of Silicon Valley in large economies like the US and replicated in France, Germany, Japan, the UK, and elsewhere. Small country economies like Israel, Ireland and Singapore, with little domestic demand for technology, developed unique approaches of exporting knowledge creation with excellent outcomes.

Developing country SMEs in partnership with government planners and foreign investors are working to create technology capacity and ensure their future in a knowledge-based world. Much energy is directed at replicating the strategies that made SMEs in Israel, Ireland, Korea, Singapore and Taiwan so successful—the development of disruptive technologies for global markets with government and donor monies supporting technology creation and VC initiatives to finance innovation.

Are these the best strategies with the greatest chances of success? Do alternatives exist, to build from a base of technical needs for the local market instead, to move developing country SMEs up the path of knowledge creation incrementally with greater numbers of enterprises succeeding domestically.
and help position a few for entry into world markets? If yes, how can developing country governments support such a strategy to generate new wealth and prosperity?

In this article I present a six point GoForward plan for government planners on how to scale up innovation and attract the resources necessary to achieve innovation growth. I draw upon my experiences in transacting seed and early stage VC investments in technology for the oil/gas, IT, biotech and medical industries from Central & East Europe (CEE) and the Commonwealth of Independent States (the CIS, countries of the former Soviet Union). These countries have many similarities with others in Africa, Asia/Pacific and Latin America where learning curve lessons presented are transferable, especially those with economies dominated by natural resources.

The allure of global technology markets

Emerging market and developing country governments see the business and financial successes of SMEs solving global needs and encourage their enterprises to attack world markets with public works initiatives to support this strategy. Actions of the Russian Government (RG) illustrate the commitments that governments execute to jump into the global technology, commercialization and VC game. The RG is spending billions of petrodollars for the creation of new technology in IT, biotech, nanotechnology, medical and the like. It is investing state money for infrastructure projects like technoparks, incubators and the launch of a 500 million dollar fund-of-funds modeled after Israeli’s Yozma fund-of-funds scheme, all with the intention of taking a seat at the table of global technology development. Global powerhouses in multiple industries—Intel, Siemens, Motorola, Microsoft, Boeing, IBM, United Technologies, Cadence and Sun—established Russian R&D centers and selectively incorporated Russian technology into their products. A few US VC funds invested in Russian innovation.

Yet with all this capital and horsepower invested and to-be-invested, something is amiss in Russia. A critical mass of seed and early stage SME investment opportunities do not exist in Russia for domestic or foreign VCs. This is not due to a lack of money as the economy is awash with capital and investors looking for opportunities. And Russia has advantages not enjoyed by other developing countries: Soviet scientific accomplishments, leading universities and world class researchers. Leveraging this foundation into a knowledge-based economy that competes with the best from the East and the West is a real challenge.

**Few GameChanging technologies**

Over the last seven years, Innovative Ventures Inc. and other VC investors evaluated hundreds of Russian and CIS technology deals in IT, telecoms, biotech and medical to name a few, yet collectively we have invested in only twelve. Specifically, over the past three years, we’ve looked at oil exploration and production (E&P) technologies for investment. Our findings provide a microcosm and a reflection of what is happening in the market and why so few VC investments in technology have been transacted in Russia.

Only 2 percent of the E&P innovations we evaluated (Figure 1) have the performance characteristics that one might classify as GameChanging: disruptive technology with superior performance or high cost reduction features. Such GameChanging benefits are required to catch the attention of global customers and investors, and compete against well entrenched competitors.

Even though the technologies we evaluated had interesting features, they are not ready for customers or venture capital. They are R&D stage concepts and require money and time for testing and development, to get them market ready, customer
ready and advanced enough for VC investment.

Our findings disprove the notion that Russian institutes and SMEs have great technologies, but investors are blind to the potential. The truth is that institutes & SMEs have great ideas, but customers buy products not concepts, and investors invest in deals, not conceptual stage ideas.

Returning to Figure 1, 52 percent of the technologies were rejected due to poor descriptions of what value the idea create, inconclusive performance data, and competitive benchmarking. Many of these ideas appear interesting and worth a second look if only reliable performance data was available. Rejection was not due to issues of IP, lack of business plans, management, or capital markets.

Good test data is essential to prove performance benefits. Once an SME decides to compete in tech markets, it positions itself against global competitors, many with deep access to customers and a customer-oriented mindset that provides buyers with the information they require to make purchase decisions.

Even with good performance data, attacking international markets requires disruptive technologies to capture the attention of global buyers and investors. However, GameChanging technologies are few and far between, even from technology powerhouses located in small and big country economies.

If the chances of creating disruptive solutions are so slim, what can a country, its scientists, universities and SMEs do to get into the technology and commercialization business? Given potential but no immediate GameChanging technologies in oil & E&P, IT, biotech, etc., what can Russia, with lots of money and talent, but only ideas, do to re-build its place in the knowledge world? What actions can countries take when they lack the technical base that Russia, Kazakhstan and others have to move up the innovation value-chain? Let's return to Russia to see what an alternative strategy might be and its learning curve lessons for others.

Overlooked opportunities in the domestic sector

WHILE FEW RUSSIAN INNOVATIONS have GameChanging qualities for international buyers, others (Figure 2) have value in domestic E&P. These ideas and products are low cost solutions that give customers (both Russian and international oil companies) almost world class performance, but with lower prices to Western competitors. Such low cost technologies attract price sensitive users that seek cost/price competitive solutions.

What makes this set of opportunities interesting is that they represent an alternative to pursuing a GameChanging strategy. Instead of trying to outperform competitors on all fronts, one can build a locally competitive SME technology sector for domestic use. Once this base is established, new resources can be invested to grow internationally competitive enterprises.

Given higher probabilities of growing a locally competitive technology sector, a GoForward strategy exists to build technology platforms in and around strategic assets vs. diversifying resources away from natural advantages. And if overlooked potential exists in tech for the hydrocarbon business, do overlooked sectors exist in other industries to 'jump-start' more tech creation and deployment?

The GoForward plan in technology and knowledge creation

ACTION ITEM #1: TARGET DOMESTIC USERS FIRST

SMEs AND GOVERNMENTS cite the low absorption rate of domestic users as the reason to pursue a GameChanging innovation strategy for world markets. Yet every country has industries that are knowledge based; some are clusters while others exist from natural advantages.

The automobile industry is a tech business with excellent growth in the CEE and the CIS as Ford, General Motors, Toyota, VW, Peugeot and others ramp up production in Russia and Slovakia to meet regional demand. These auto multinationals need to build the domestic auto component supply chain to a Western equivalent to meet their business plans just as Shell, Chevron and other oil companies need more and better oil field service suppliers in the CIS. And both industries seek solutions to localize more purchasing and satisfy local content regulations.

Yet Russia’s forward plans to build knowledge based sectors include the usual list of candidates (e.g., IT, bio & nanotech, etc.) but not auto components, oil field services and mineral extraction/processing; sectors with immediate pay-offs to catalyze a chain reaction in domestic tech absorption.

Where single technology hubs are less obvious, other SME development approaches are possible, e.g., in logistics, where multiple technologies intersect. For instance, Latvia sits on the Baltic Sea with new technologies required in IT, warehousing and transportation to grow a nascent logistics platform into a regional distribution powerhouse.

ACTION ITEM #2: PROVIDE ‘MINI GRANTS’ TO DOCUMENT BUSINESS OPPORTUNITIES

Once domestic industry tech hubs and opportunities are identified, fund a 'mini-grant' program to define the business opportunity for proposed technologies. The mini-grant is not intended to fund an entire business plan, but a 3-4 page document of the potential of the proposed technology. Typical mini-grants might be in the size of $3,000-$10,000.

ACTION ITEM #3: CAPITALIZE A ‘PROOF OF CONCEPT’ FUND

Commercialization of new technology starts with R&D and product development monies to demonstrate 'proof of concept' and the value of novel ideas. Early stage SMEs frequently lack the money to initiate 'proof of concept' testing. Yet they are only able to approach customers when they clearly present technology strengths and weaknesses, conducted to a comprehensive analysis under different user conditions. Then, monies can be invested to enhance the technology. A Proof of Concept Fund finances the costs of testing a technology and benchmarking it to competition and alternatives.
To invest capital wisely, mandate that developers and companies benchmark the technology early and often. Most technologies have specific applications where they perform best and create the most value-added, and the developer needs to know the range of user conditions, performance and cost characteristics to create and capture the value that the technology provides. This can only be accomplished by testing the technology at regular intervals, and comparing performance results to what buyers have from competitors, whether they are domestic or international companies.

**ACTION ITEM #4: INVENTORY SME/INSTITUTE TECHNOLOGIES AND PUBLISH AS A DATABASE**

Provide an Organizational Service (OS) that gives customers and investors the information needed to consider technology from your country:

1. SMEs/institutes organized by technology, product and market segment, with full contact information
2. Benefits of their technology, cost and performance
3. Performance and cost benchmarked against domestic and international competitors with data generated to international testing standards
4. Stage of development, i.e., R&D, product development, alpha/beta testing, etc.
5. Product development plan with timetable and milestone inflection points, line item budgets
6. Patents issued or filed, by country, date and number, and competing technologies similar in form or function

Publish this information as a database hosted on the Internet and searchable by keywords like technology or market.

**ACTION ITEM #5: OFFER TARGETED BUSINESS DEVELOPMENT SUPPORT**

Too often innovations developed in academia remain on the shelf since scientists lack the knowledge to make the business case for the technology, the energy and drive to move them into the market; many scientists and (some) businesses lack the skills to make the transition from development to commercialization and growth.

Create a business development office with an outreach community which actively works with the OS to 'scout' for opportunities in the SME community and academia, identify and develop interesting projects for financing by the 'mini-grant' and Proof of Concept programs, and help sell innovations from academia/SMEs to customers.

**ACTION ITEM #6: ESTABLISH AN IP FACILITY TO PROTECT YOUR COUNTRY'S INTELLECTUAL ASSETS**

The IP Facility pays legal and other costs of filing domestic or international patents with costs reimbursed through revenues generated from product sales. Such repayments replenish the Facility so it becomes a revolving instrument with a one-time investment.

Scientists and businessmen are rightfully proud when they create new innovations, and they frequently announce their solutions to others prematurely and inadvertently, before protecting IP. One responsibility of the business development office is to identify IP early in the development cycle and work with legal council to protect the technology. Another responsibility of the business developers is to educate and sensitize scientists and SME management to the issues in IP protection.

**Concluding remarks**

**NEW ZEALAND IS A FITTING SUCCESS STORY** for my conclusion. While it is not a developing country, it is a small and geographically remote country and its success in transitioning from low tech to high tech is illustrative of how a domestic focus created a technology SME industry.

In the mid 1990s, New Zealand government planners invested capital to create more flavorful and different varieties of wine, cows and lamb with more meat and less fat. Their focus was on new solutions for domestic needs in agriculture and animal husbandry, not global applications in IT, nanotechnology, biotech, etc., areas where New Zealand had little comparative advantage. Five years later, government initiatives yielded results and VC investors began investing in New Zealand SMEs to commercialize their innovations.

Fast forward to 2006 and New Zealand meat and wine are found in Australia, Europe, Japan, Russia and the US. New Zealand SMEs sell tech products and services to Australian, European and US wine producers and animal growers, truly a win-win for all. Build the deal flow first, and then customers and investors will come...

Thomas D. Nastas is President of Innovative Ventures, Inc., (www.IVlpe.com) with offices in the USA and Russia. Mr. Nastas is also Instructor, MBA program, American Institute of Business & Economics College, Moscow. He can be reached at Tom@IVlpe.com.
Science and Technology Promote Africa’s Conservation Agenda

BY EMMANUEL KORO

AS CONSERVATIONISTS WORLDWIDE BATTLE to conserve natural resources, Southern African conservationists, scientists, and rural communities have joined hands to promote conservation through science and technology.

The wonders that information and communication technology (ICT) can do towards promoting conservation and development were recently highlighted when Southern African and European scientists and representatives of African and European conservation and development agencies met in Benoni Town of South Africa. The scientists discussed the impact of using ICTs such as cell phones, Global Information Systems (GIS), Global Positioning Systems (GPS), cameras, and two-way radios to promote conservation and development.

The meeting took place at a time when a new project, Technology for Conservation and Development (t4cd), funded by Vodacom Foundation and Vodafone Group Foundation, is being implemented by the South Africa-based conservation agency, ResourceAfrica, together with seven communities around the Great Limpopo Transfrontier Park.

The t4cd Project involves using cell phones, which help rural communities to receive Short Message Services (SMS) from computers of Kruger National Park managers, requesting them to carry out activities that help stop poaching, and inviting them to attend urgent conservation meetings. The system will also be used to inform locals of potentially dangerous weather conditions. Kruger National Park is part of the Great Limpopo Transfrontier Park, which links Mozambique’s Limpopo National Park and Zimbabwe’s Gonarezhou National Park into one big transfrontier park.

Technology for conservation and development

THE T4CD PROJECT DEMONSTRATES how science and technology can be used as valuable tools to help balance the often conflicting needs of society and conservation. At present, rangers can communicate among themselves within the park through two-way radio systems but they cannot communicate with community members. The radio system needs to be improved in order to expand communication and enhance conservation.

From a development standpoint, SMS will largely help rural communities running ecotourism projects to communicate cheaply with tourists from far away or from different countries and continents wishing to make direct accommodation bookings in rural Southern Africa.

Cell phones create business opportunities for rural communities

ALSO, THROUGH THE USE OF CELL PHONES, communities in rural South Africa and Zimbabwe can now com-
municate with manufacturers of agricultural inputs and transport providers and negotiate for cheaper input deals and cheaper rates to send their produce to the nearest markets. The fact that they get cheaper deals after negotiating with the transport service providers as well as retailers of agricultural inputs leaves them with handsome incomes to invest in other activities that support their socio-economic uplifting. Some of this income is used to pay for their children’s education and health services.

Roseline Murota of the Southern African Alliance (SAFIRE), based in Zimbabwe, said that Zimbabwean rural communities in the South-East Lowveld and in Matebeleland were currently benefiting from using ICT to promote conservation and development. She said that these communities have websites written in local languages such as Shona and Ndebele. Through these websites they exchange information on attractive agricultural markets and also find out where they can purchase agricultural inputs and machinery cheaply.

She said, “The positive impacts of using computers and the Internet include improvement of livelihoods of rural communities and sharing of traditional conservation methods. These communities also use video cameras to exchange information on better management of natural resources.”

Technology for illiterate people

THE TECHNICAL REPRESENTATIVE of a wildlife cyber-tracking project, Douw Swanepoel, said that their technology was specially designed for illiterate people, allowing them to use an advanced hand-held computer-based system that works on symbols or icons. The cyber-tracking technology involves using a hand-held computer that records the state of natural resources, including wildlife. It was developed in South Africa by a South African, Louis Libenberg, about 10 years ago.

“The beauty of this technology is that one does not need to be able to read in order to do game counts or document the state of natural resources in national parks or wilderness areas,” said Swanepoel.

The cyber-tracker system works on screens with different animal or plant species’ icons. So for example, if you see an elephant, the first screen will allow you to choose whether you have seen a tree, a bird or an animal. In the case it’s an animal, you choose the animal icon and it opens up a new screen that asks you which animal you are seeing. The screen shows pictures of all the different animals and you just touch on the elephant picture. When you touch on the elephant icon, a new screen that asks you to identify the sex and age of the elephant opens up with icons of a man, woman and a baby and there is also a little space that opens up asking you to state how many baby elephants, or adult male and female elephants you have seen.

Tourism and natural resources conservation

"THE TOURISM INDUSTRY can not flourish if natural resources are not appropriately managed," said Swanepoel. Most of the water the people of this region drink in cities and rural areas comes from wetlands in protected areas. Technologies such as ICTs can offer new solutions for protecting these wetland areas.

"In the Zambezi valley in Mozambique the t4cd Project is working with the World Conservation Union (IUCN) in applying Geographical Information Systems (GIS) and other spatial rendering hardware or software combinations so that they can support wet lands management initiatives," said ResourceAfrica t4cd Project Manager, Mr. Muroro.

Working together with the South Africa-based Southern African Wildlife College, the t4cd Project has already drafted a week-long t4cd training course.

"This one week course will be rolled out in the region as a technology training course in the use of Information Communication Technologies (ICTs) for conservation and development and will be appropriately named t4cd,” said Muroro.

“Voices from the Field” provides first-hand insight into issues of current concern to the development community. To participate, send your stories to: devoutreach@worldbank.org. Make your voice heard.

Emmanuel Koro is an Environment and Development Communication Specialist and also the President of Sub Saharan Africa Forum on Environment Communicators (SAFE).
SCIENCE, TECHNOLOGY AND INNOVATION DISCUSSION PAPER SERIES, a peer-reviewed, online publication sponsored by the Science, Technology and Innovation (STI) Team in the Education Department, Human Development Network, the World Bank. This series is designed to be a vehicle for discussing and disseminating issues related to STI Capacity Building.

www.worldbank.org/sti

CGIAR VIRTUAL LIBRARY (CGVLIBRARY) is an internet gateway that allows development professionals to search an interdisciplinary array of leading databases on agriculture, hunger, poverty, and the environment. Developed by the Consultative Group on International Agricultural Research (CGIAR) and funded by the World Bank, the CGVLibrary enables users to retrieve thousands of full-text documents, abstracts, or references from the libraries of CGIAR agricultural research centers, online journals, and numerous other electronic holdings, including those of the World Bank.

http://library.cgiar.org

UN EUROPEAN COMMISSION—INNOVATION AND TECHNOLOGY TRANSFER
This is a reference source for European Commission publications on innovation and technology transfer, grouped by type: periodicals, studies, conference proceedings, and official documents. Titles are given in English, but other language versions often exist as well. Links to the electronic format edition are provided when available.


WORLD FEDERATION OF ENGINEERING ORGANIZATIONS (WFEO) is committed to the advancement of the world engineering profession for the benefit of mankind. It particularly works to assist development of the engineering profession, and in the sharing, exchange and transfer of technology from one country to another. It works to improve the understanding of engineering, the quality of engineering education and training, and the ethics and standards of engineering practice.

http://www.unesco.org/wfeo

THE POVERTY AND GROWTH BLOG is maintained by the World Bank Institute’s Poverty and Growth Program (PGP). This blog is targeted at alumni from PGP courses, partners, researchers, academia, civil society, government officials and, in general, the broad public interested in poverty reduction. The aim is to share knowledge and improve common understanding of the challenges of reducing poverty and accelerating growth. To facilitate this process, the blog brings you timely news, resources, tools, ideas and commentary on poverty-related topics.

http://pgpblog.worldbank.org/

TERRAGREEN is an e-magazine that reports significant shakeouts in India’s energy, environment and sustainable development scenarios, once every two weeks. This is a magazine launched by TERI—a unique developing country institution deeply committed to every aspect of saving the environment through sustainable development—to take to millions of concerned individuals across the world analytical, unbiased and straightforward reportage about the environment in India.

www.teriin.org/terragreen

YOUTHINK! LANGUAGE EDITIONS. The Bank’s youth site Youthink! is now being published in Chinese, French and Spanish. The English version of the site, which won the 2006 Webby Award for Activism, has also seen an increase in visitor traffic by 66% since October 2005. Youthink! has launched a new bulletin board for you to share your thoughts on the issues that matter most to you, and see what other Youthink! readers have to say.

http://youthink.worldbank.org/
This is a new World Bank flagship publication addressing the critical role being played by information and communication technologies (ICT) in economic development. It provides a global overview of ICT trends and policies in developing countries, covering issues such as financing infrastructure, the importance of public-private partnerships and effective competition to extending access, using ICT in doing business and formulating national e-strategies. The ICT At-a-Glance tables for 144 economies show the most recent national data on key indicators of ICT development.

The World Economic Forum continues its tradition of excellence with the 27th edition of the annual Global Competitiveness Report featuring the latest national statistics and results of the Executive Opinion Survey, which captures the perception of over 10,000 business leaders. The report provides the most comprehensive assessment of 117 developed and emerging economies. The report also showcases the latest thinking and research on issues of immediate relevance for business leaders and policy-makers.

Written by 27 World Bank experts, this book aims to increase awareness and understanding of global issues. It covers four broad themes (global economy, global human development, global environment, and global governance). Each chapter defines a specific issue and identifies what makes it global in scope; explores the consequences of addressing or not addressing it; discusses solutions, controversies, and international actions already under way or proposed; and provides a brief review of the World Bank's own perspectives on the global issue in question and its role in seeking solutions. The book can be ordered online at http://publications.worldbank.org/ecommerce or Amazon.com.

Following the widespread success of *The Creative City*, this new book, aided by international case studies, explains how to reassess urban potential so that cities can strengthen their identity and adapt to the changing global terms of trade and mass migration. It explores the deeper fault-lines, paradoxes and strategic dilemmas that make creating the "good city" so difficult.

This book aims to improve the relationship between science and society. The discussion involves six themes: communicating between plural perspectives; accepting and learning how to manage uncertainty, complexity and value commitments; acknowledging new conceptions of knowledge; implementing transparency, openness and participation in science policy; valuing community-based research; and exploring how new ICT can support inclusive governance. Taken together, these themes provide both a framework and a vision for the changes that are occurring.

The essays in this volume—by a group of South African researchers from different institutes and diverse cultural backgrounds—bring to light a transcendent dimension of our human nature that is often overlooked in the international science-and-religion debate. This is a dimension of our humanity that transcends what the sciences are able to study because it is what enables us to be the creators and judges of science. It is also what endows us with the freedom and responsibility of deciding which, if any, religion to follow.
CALENDAR

JANUARY 2007
22-24   Phacilitate Vaccine Forum
        Baltimore, MD
        www.phacilitate.co.uk/pages/baltimore_vac/index.html
24-28   World Economic Forum Annual Meeting:
        The Shifting Power Equation
        Davos, Switzerland
        www.weforum.org

FEBRUARY 2007
13-15   Global Forum: Building Science, Technology,
        and Innovation Capacity for Sustainable Growth
        and Poverty Reduction
        Washington, DC
        www.worldbank.org/stiglobalforum

MARCH 2007
8-14    Commission on Investment, Technology and
        Related Financial Issues, 11th session
        Geneva, Switzerland
        www.unctad.org

APRIL 2007
14-15   Spring Meetings of the World Bank Group
        and the International Monetary Fund
        Washington, DC

MAY 2007
21-25   Commission on Science and Technology for
        Development, 10th session, Geneva,
        Switzerland
        www.unctad.org
23-25   11th African Oil and Gas, Trade and Finance
        Conference and Exhibition
        Nairobi, Kenya
        www.unctad.org

JUNE 2007
4-8     4th Dubrovnik Conference on Sustainable
        Development of Energy, Water, and
        Environment Systems
        Dubrovnik, Croatia
        www.dubrovnik2007.fsib.hr

SUBSCRIBERS FROM DEVELOPING COUNTRIES WILL CONTINUE TO RECEIVE
THE MAGAZINE FREE OF CHARGE.

SUBSCRIPTION FEE APPLIES TO READERS IN THE FOLLOWING DEVELOPED COUNTRIES:

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland,
Ireland, Italy, Japan, Kuwait, Luxembourg, Monaco, Netherlands, New Zealand, Norway,
Oman, Portugal, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, United
States, and Vatican City.

Please print or type all information

☐ YES, sign me up for Development Outreach
for 2007 for just $18
(three issues per calendar year,
January-December)

NAME ________________________________
TITLE ________________________________
ORGANIZATION _______________________
ADDRESS ______________________________
_______________________________________
CITY AND STATE OR PROVINCE ____________
COUNTRY ______________________________
ZIP / POSTAL CODE _____________________
PHONE ________________________________
FAX _________________________________
E-MAIL ______________________________

Please do not send cash. Make checks payable to Development OUTREACH/WBI.
☐ Check no. ___________ in the amount of $ _______ is enclosed.

Mail order to:
Editor, Development OUTREACH
The World Bank
1818 H Street, NW, Room J4-108
Washington, DC 20433 USA
A GLOBAL SEMINAR FOR SENIOR POLICYMAKERS
Capital Flows, Financial Integration and Stability
Paris, France, April 23-26, 2007

The global economy has entered the fourth year of continuous growth.
However, as global current account imbalances have widened to unpre-
cedented levels and the US economy is slowing down, there are heightened risks
facing the global economy. In addition, capital flows have continued to be
unevenly distributed amongst developing countries leaving most of the low
income countries out of financial and development. This policy
seminar provides cutting edge analysis of the current issues in managing
capital flow volatility, causes and implications of the global imbalances, and
policy options for ensuring macro stability. First, the seminar discusses stylized
facts on the capital flows and global imbalances and its implications. Second,
challenges and issues related to financial integration, capital flight, herding and
contagion are discussed. Third, the seminar focuses on factors determining the
external positions of various groups of countries including the exchange rate
arrangements, monetary unions, pegged exchange rates and their implications.
Finally, the seminar discusses the reform of international financial architecture,
including Basel II recommendations, and policy options to maintain financial
stability and promote financial deepening and development.

MODULES
• Current challenges to the global economy;
• International financial integration and deepening;
• Global imbalances and exchange rate regimes;
• Policy options to maintain financial stability and promote development.

AUDIENCE
This fee-based seminar ($1500) targets at senior level government officials,
officials from central banks, ministries of finance, financial regulatory
agencies, and investment banks, as well as staff from international financial
organizations.

CONTACT
Task Manager: Yan Wang
Tel: 1-202-458-1411, fax 1-202-676-9810
Program Assistant: Maxine Alonso Pineda
Tel: 1-202-473-0884, email: mpineda1@worldbank.org
http://www.worldbank.org/wbi/capitalflows
Managing the Implementation of Development Projects
A Resource Kit on CD-ROM
For Instructors and Practitioners

This Resource Kit on CD-ROM provides print-based learning materials on project implementation management. The 12 modules are designed to support trainers in delivering up to five weeks of face-to-face instruction; but they will also be of interest to anyone involved in managing projects.

The 12 modules are:

1. Understanding the Project and Project Management
2. Structuring the Project Organization
3. Building the Team
4. Analyzing the Project Context
5. Refining Objectives, Scope, and Other Parameters
6. Preparing the Work Breakdown Structure, Responsibility Matrix, and Master Summary Schedule
7. Planning and Scheduling with the Critical Path Method
8. Obtaining Management Approval and Support
9. Designing Control and Reporting Systems (Time, Cost, Resources, and Scope (Performance and Quality))
10. Organizing Procurement
11. Executing and Controlling the Work
12. Terminating the Project

The Resource Kit allows users to:

- Print out materials (some 2,000 pages)
- Preview and browse the material on the CD-ROM for self-directed learning
- Search and sort the materials by topic as well as by category of learning resource (for example, case study, exercise, lecture, reading).

These learning materials are designed for officials from government ministries and departments, public and private corporations, or project agencies that will be overseeing the implementation of development projects.

Each module includes:

- Performance-based instructional objectives that are specific, measurable, and observable; on-the-job project management tasks that the module addresses; module and session outlines with a timetable of activities; scripted lectures, including corresponding visuals; case studies, exercises, and solution sets; teaching notes for the instructor for each exercise and case study; self-assessment questions and solutions; and selected readings.


WBI publications are available from the World Bank’s InfoShop and from local distributors worldwide.