Report of the
Third World Academy of Sciences

Building Scientific Capacity

A TWAS Perspective






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The **Third World Academy of Sciences** (TWAS) is an autonomous international scientific organization dedicated to promoting scientific capacity and excellence for sustainable development in the South.

TWAS was founded in Trieste, Italy, in 1983 by a group of distinguished scientists from the South under the leadership of Nobel laureate Abdus Salam of Pakistan, and officially launched by the then-secretary general of the United Nations, Javier Perez de Cuellar, in 1985. The Academy's operational expenses are largely covered by generous contributions from the Italian government.

Since 1986 TWAS has supported scientific research in 100 countries in the South through a variety of programmes. More than 2,000 eminent scientists world-wide, including TWAS members, peer review proposals free-of-charge for research grants, fellowships and awards that are submitted to the Academy by scientists and institutions from developing countries.

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Acronyms Used

AFRAND	African Foundation for Research
AIMS	African Institute for Mathematical Sciences
ATCA	African Technical Cooperation Agency, African Development Bank
CERN	European Organization for Nuclear Research
CNPq	Brazilian National Research Council
COMSATS	Commission on Science and Technology for Sustainable Development in the South
CSIR	Council of Scientific and Industrial Research, India
DFID	Department for International Development, UK
GDP	Gross Domestic Product
GEF	Global Environment Facility
IAC	InterAcademy Council
IANAS	InterAmerican Network of Academies of Sciences
IAP	InterAcademy Panel on International Issues
IAS	Institute of Advanced Study, UNU
ICGEB	International Centre for Genetic Engineering and Biotechnology
ICSU	International Council for Science
ICT	Information and Communication Technology
ICTP	Abdus Salam International Centre for Theoretical Physics
IDRC	International Development Research Centre
ISTS	Initiative on Science and Technology for Sustainability
LDCs	Least Developed Countries
MDGs	Millennium Development Goals
MSI	Millennium Science Initiative
NASAC	Network of African Science Academies
NASIC	Network of Academies of Sciences in Islamic Countries
OECD	Organization for Economic Cooperation and Development
RANDFORUM	Research and Development Forum for Science-Led Development in Africa
SACs	Scientifically Advanced Countries
SDCs	Scientifically Developing Countries
Sida-SAREC	Department for Research Cooperation (SAREC) of the Swedish International Development Cooperation Agency (Sida)
SIG	Science Initiative Group
SLCs	Scientifically Lagging Countries
SPCs	Scientifically Proficient Countries
TCDC	Special Unit for Technical Cooperation among Developing Countries, UNDP
TOKTEN	Transfer of Know-how and Technology through Expatriate Nationals
TWAS	Third World Academy of Sciences
TWNSO	Third World Network of Scientific Organizations
TWOWS	Third World Organization for Women in Science
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNU	United Nations University
WEHAB	Water, Environment, Health, Agriculture and Biodiversity
WHO	World Health Organization
WMO	World Meteorological Organization
WSIS	World Summit on the Information Society
WSSD	World Summit for Sustainable Development

Foreword

Building Scientific Capacity: A TWAS Perspective is the Academy's second research report, following the publication of *Safe Drinking Water: The need, the problem, solutions and an action plan.* The series, inaugurated in 2000, is designed to tap the broad-ranging expertise of TWAS's membership as part of a larger effort to examine critical science-related issues of importance both to the North and South.

This report offers an additional viewpoint on an issue that has recently received a great deal of attention: scientific capacity building, particularly in the South. For example, the RAND Corporation, the InterAcademy Council and the United Nations, through its Millennium Development Goals (MDGs), have all examined in detail strategies for the promotion of scientific capacity with special attention to the challenges faced by the developing world. The purpose of this report is to complement the wide-ranging discussion now taking place and to provide a distinct perspective on this issue as seen through the eyes of scientists and scientific institutions in the South.

I would like to commend Dorairajan Balasubramanian (TWAS Fellow 1997) for researching and preparing the text for this report. I am also grateful to the staff of the TWAS Public Information Office – Daniel Schaffer and Peter McGrath for their expert editorial assistance, and Gisela Isten for overseeing the layout and printing of the report. A special thanks should be extended to Mohamed H.A. Hassan, TWAS executive director, for his invaluable input on many of the broad issues that shape the analysis of the report that follows.

Many observers now agree that scientific capacity building holds the key to long-term economic progress in the South. We believe that TWAS has an important contribution to make in this effort and we hope that this report will add constructive insights for advancing the goals that we all share.

C.N.R. Rao
President, TWAS
Trieste, Italy
Autumn 2004

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Executive Summary

Today, the world consists of 192 countries. However, fewer than 40 are classed as 'developed' countries where people enjoy high standards of personal health and wealth.

The level of development – in terms of both the economic well-being and the health of its population – of the remaining 150 or so nations – many of which are located in the South – varies widely.

The Millennium Development Goals, announced by UN Secretary General Kofi Annan in 2000, call for the elimination or reduction of poverty and hunger, universal education, gender equality, improving the health of mothers and children, combating diseases, sustainable use of environmental resources, and development of fair and open trading regulations and global partnerships (*www.un.org/millenniumgoals*).

The only viable and proven way to achieve these Millennium Development Goals is through the application of science and technology. Indeed, over the past 200 years, developed countries have effectively used science and technology to drive their national progress. As a common heritage of all humankind, scientific knowledge can also be used as an effective engine for national development by the countries of the South.

For developing countries to fully exploit all that science can offer, however, they need to build and sustain scientific capacity, both at the individual and institutional level. The challenge is to nurture and maintain a critical mass of highly qualified and innovative scientists and technologists in every country and equip them with the means to pursue their research objectives. To achieve this goal, the following action plan is recommended:

- ***Create and Strengthen Centres of Leadership and Excellence***, especially in least developed countries (LDCs) and scientifically lagging countries, by identifying leaders and research teams, providing them with autonomy, financial stability, modern equipment and access to information technologies and international peer groups.

- ***Support Fellowships, Associateships and Training Programmes*** that keep scientists, technologists, technicians and students up-to-date with the latest information and connected with other research and educational centres around the world.
- ***Promote Scientific and Technological Cooperation in the South*** through South-South exchange fellowships for doctoral and postdoctoral researchers. In particular, the major developing countries should make significant contributions towards the scientific development of the more resource-strapped countries.
- ***Create Institutional Networks to Address Common Problems*** relating to issues of regional concern or common interest such as access to safe drinking water and improved sanitation, wise use of environmental resources and efforts to achieve sustainable development. Such networks should promote joint research projects and conferences, workshops and symposia that allow for the constant exchange of ideas.
- ***Publicize and Share Successful Experiences*** that can serve as models for the involvement of scientists, policy makers and planners in using science for national development. Successful innovative experiences in one country can often inspire and motivate other countries. Efforts should target both the media and policy makers, and highlight the fact that, despite problems, scientists in the South have developed many creative answers to address and solve critical development issues.
- ***Develop Interdisciplinary Panels of Experts in the South*** that can offer timely, authoritative and locally relevant advice to governments and policy makers on issues of such critical importance as biotechnology and renewable energy. These interdisciplinary panels should also organize 'South Science Summits' to help political leaders in the South place science and technology at the top of their agendas, making science and technology an integral part of development programmes.
- ***Create and Support Merit-based Academies of Science in the South*** that will help promote and sustain scholarship, act as guardians of ethical values in science, serve as role models for the young, recognize and reward good work, interact with other academies and scholastic bodies, and engage governments in matters where science and policy meet, including development issues.
- ***Mobilize Expatriates and Institutions in the North*** enabling the 'brain drain' to be converted, in part, into a 'brain gain'. Scientists in the North, particularly those from developing countries, should be encouraged to work on major Third World problems, and institutions in the North should be encouraged to assist in building scientific capacity and excellence in the South.

- ***Provide Equitable Access to Currently Available Knowledge***, create virtual networks among teams of research scientists working in different countries, and promote advanced wireless digital communication systems that are most relevant to developing countries.
- ***Reform Educational Systems*** so that every citizen is able to understand general scientific concepts and to benefit from this knowledge, and so that the brightest students are motivated to pursue careers in science. This should involve national and international collaborative efforts aimed at both students and teachers, and make full use of advances in information and communication technologies.
- ***Popularize Science*** so that the message of science reaches all citizens, young and old alike, including politicians and policy makers. 'Science for All' should be a conviction that motivates governments, voluntary organizations, educators and scientists.
- ***Engage the Private and Nongovernmental Sectors*** as agents for national development by supporting science and technology through in-house and extramural research, training, recruitment and related modes of support.
- ***Persuade Governments to Commit to Science and Technology*** by investing adequately in science, education and health, setting a target for the science sector to receive at least 1 percent of the gross domestic product (GDP) within 10 years.

TWAS: 20 Years of Capacity Building

The globe of ours is inhabited by two distinct species of humans – the developed and the developing. What is it that makes these two species of humans? Is it colour, creed or religion? Is it cultural heritage?
The answer in all cases is No. What distinguishes one species from the other is the ambition, the empowerment and the élan, which basically stems from their differing mastery and utilization of present-day science and technology.

Abdus Salam, 1988

When the Third World Academy of Sciences (TWAS) was launched in the mid-1980s, the words 'capacity' and 'building' had yet to appear side-by-side. Their singular definitions remained both distinct and simple to convey: 'capacity' meant the ability to get something done and 'building' usually referred to a structure not a process.

Today, however, in the increasingly integrated worlds of science and society, the two words have been linked together to describe one of the most critical issues facing our global community, especially nations in the developing world: How can every nation develop a strong foundation in science and technology capable of serving the critical social and economic needs of its citizens?

The phrase 'capacity building' may not have existed 20 years ago but efforts to build scientific know-how and skills were being pursued even then by a select group of organizations. Indeed TWAS – and the Abdus Salam International Centre for Theoretical Physics (ICTP) – were created for just that purpose: to nurture the skills of a sufficient number of scientists and to help establish conditions within each country that would encourage native-born scientists to live and work at home.

Capacity building may be the term used today to describe these efforts but the fact is that concrete strategies for advancing this goal have been with us for some time. Where we have fallen short is on how best to advance such strategies, how to assess their effectiveness, and how to transfer knowledge and experience about capacity building from one nation to another. In short, we have known for some time what needs to be done but we have been less sure on how to successfully do it.

We believe that TWAS's 20 years of experience in capacity building can provide a valuable perspective on this discussion. It is for this reason that

TWAS has decided to publish this brief report: *Building Scientific Capacity: A TWAS Perspective*.

The Academy is pleased by the rising level of attention that has recently been focused on scientific capacity building issues. The publication of the InterAcademy Council's (IAC) report in 2004, *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology* and the United Nations (UN) Millennium Project's *Report of Task Force 10 on Science, Technology and Innovation* (an interim report was published in February 2004; the final report is scheduled for publication in December 2004) are just two examples of this growing discussion. The G-8, representing the world's richest countries, and the G-77, representing the world's poorest countries, have also lent their voices to the issue of scientific capacity building through their sponsorship of conferences, workshops and publications focusing on the issue. So too have such international organizations as the Third World Network of Scientific Organizations (TWNSO), the InterAcademy Panel on International Issues (IAP), the Millennium Science Initiative (MSI) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). And, of course, over the past several decades, an endless number of nongovernmental institutions have laboured to apply appropriate science and technology to address critical economic and social needs.

Beyond the publication of reports and articles, a host of institutions – international, governmental and nongovernmental – have recently focused on scientific capacity building issues, especially in developing countries. These organizations have included, most notably, the United Nations itself with its emphasis on the Millennium Development Goals (MDGs). First announced in 2000 by UN Secretary General Kofi Annan, these goals have quickly become the international standard for measuring progress – or sadly the lack of progress – in improving the material well-being of people living in the South. Focusing on such critical concerns as poverty and hunger alleviation, education, gender equality, improvements in the health of mothers and children, combating disease, sustainable use of natural resources, and development of fair and open trading regulations, the MDGs have provided both a roadmap for action and, at the same time, clearly delineated signposts that will help us determine if progress is indeed taking place in the years and decades ahead.

The broad principles outlined in the MDGs were subsequently refined in a statement issued by the Secretary General on the eve of the World Summit for Sustainable Development (WSSD) in Johannesburg, South Africa, in 2002. In his statement, the Secretary General presented “five specific areas where concrete results are both essential and achievable” for addressing critical concerns in the developing world and establishing a reasonable blueprint for progress in efforts to advance science-based sustainable development. These areas include water and sanitation, energy, health, agriculture and biodiversity and ecosystem management (the so-called WEHAB agenda).

Clearly, science and technology have a central role to play in both achieving the MDGs and successfully responding to the WEHAB issues. That is why the UN Commission on Sustainable Development, which meets at the UN headquarters in New York each year, has made the science and technology (S&T) community one of its nine major stakeholders. The S&T group is responsible for both monitoring and fostering progress on the goals outlined at the WSSD.

The report that follows is neither designed to speak for other organizations or to describe their worthwhile efforts. Instead, what we hope to do is add our voice to today's lively discussions on capacity building by analysing the issue from TWAS's unique perspective.

TWAS's scientific capacity efforts have been built on a stair-stepped, integrated framework based on the following principles. This report is designed to provide a detailed action plan built around essential elements that have shaped these efforts over the past two decades:

Respect, honour and support. When TWAS was launched in the mid-1980s, scientists throughout the developing world faced dismal working conditions – employment opportunities were minimal, pay was low and classroom and laboratory facilities were substandard. The standing of scientists within their own nations, never high to begin with, was on the decline as national economic development strategies focused on the ability to acquire 'off-the-shelf' technology from elsewhere, especially from the North. Science, in fact, was often viewed as an unaffordable luxury that poor nations should avoid so that they could invest their scarce resources on more immediate economic and social needs. TWAS's initial programmes were designed to counteract these trends. In fact, the Academy itself, with its merit-based membership consisting of the developing world's most prominent scientists, was designed explicitly to bestow honour and prestige among developing world scientists who remained largely unknown within their own nations. TWAS prizes, given to researchers who have accomplished important work under trying circumstances, were also intended to boost the expertise of scientists in the developing world by providing them with additional resources to improve their ability to conduct research. TWAS also launched a young scientists' awards programme, in cooperation with national science academies and research councils in the developing world. Again, the goal was to raise the level of respect and recognition for promising scientists in the developing world working under trying conditions within their own countries.

South-South cooperation. When TWAS was launched in the mid-1980s, South-South cooperation was in its infancy. There were simply not a sufficient number of institutions of excellence for a dynamic and sustained exchange of ideas to take place. Limited numbers of well-trained scientists; poorly equipped classrooms, laboratories and libraries; the exorbitant cost of travel; and currency and visa restrictions all conspired to make interactions among scientists in the South both difficult and infrequent. Today, South-South cooperation has emerged as a powerful force for change in the developing world thanks largely to the growing scientific capabilities of research centres and universities in such scientifically proficient countries as Brazil, China and India. These nations now have universities and research centres of increasing excellence capable of meeting the requirements of not only their own native-born scientists but of scientists from other developing countries who can visit these institutions to pursue both research and training activities. TWAS has played a key role in the development of South-South cooperation through its sponsorship of such initiatives as the TWAS fellowship programme. The programme recently received a considerable boost when Brazil, China and India each agreed to fund 50 fellowships a year for young scientists in less scientifically proficient countries. Specifically, the fellowships will allow scientists to pursue doctorate and post doctorate studies at institutions in sponsoring countries. The bottom line is this: South-South cooperation for scientific capacity building is now flourishing and promises to become an even greater force for change in the years ahead.

North-South cooperation. When TWAS was launched in the mid-1980s, North-South cooperation was not only limited in scope but flowed in only one direction – from the North to the South. In other words, virtually all scientific knowledge and innovation originated in the North and then was transferred, selectively, to the South. This amounted to a 'lopsided' partnership in which developing world scientists played a subservient role to their Northern counterparts. Today, science in the North continues to dominate the global scientific agenda – 80 percent of all scientists live and work in the North, which is home to less than 20 percent of the world's population. Yet the nature of that relationship is slowly evolving due to several factors. First, as noted above, the South's universities and research centres have gained a level of competence that now allows them to participate as true partners in international science initiatives. Indeed, in certain fields (for example, seismology in China and mathematics in India) the level of scientific inquiry now equals or exceeds the level of scientific inquiry in the North. Second, there is growing recognition that efforts to solve today's critical challenges – ranging from global climate change to the need to boost agricultural output to meet growing food demands – require international cooperation. And third, indigenous knowledge is increasingly viewed not as a separate source of knowledge but as an important contribution to our understanding of the natural world and the ways in which human beings interact with it. With its deeply rooted indigenous systems of knowledge, the South is the primary source of expertise in this critical area of ideas and insights. With its affiliated organizations – including TWNSO, the Third World Organization for Women in Science (TWOWS) and IAP – TWAS has played an important role in North-South cooperation. For example, TWAS's Visiting Scientist Scheme, which is co-sponsored by the International Council for Science (ICSU), UNESCO and the United Nations University's Institute for Advanced Studies (IAS), enables scientists from the North to visit institutions in the South for the exchange of information and ideas. Also, IAP, which operates under the administrative wing of TWAS, has provided a forum for merit-based science academies from both the North and South to exchange ideas and learn from one another as part of a larger effort designed to improve the ability of science academies to influence both public opinion and public policies within their nations. IAP's efforts have led to the creation of regional science academy associations in the Americas, Africa, Asia and countries with predominantly Muslim populations. In addition, IAP members have pursued cooperative programmes focusing on science education and the health of mothers and children. As scientific expertise in developing countries continues to grow and as critical economic, environmental and social problems become more global in scope, it is likely that North-South scientific cooperation will intensify in the years ahead – with positive impacts on scientific capacity building throughout the world.

Problem solving. When TWAS was launched in the mid-1980s, science played only a marginal role in economic development strategies. Indeed the prevailing belief was that developing countries would be foolish to invest a great deal of money in the development of science and technology because it would be more efficient to purchase already existing technology that had been developed in the North. Science, in short, was viewed as a luxury that developing countries could not afford. Today that perception has been largely discredited. Nations, particularly developing nations, have learned that technologies produced elsewhere may not serve their needs and that efforts to create their own appropriate technologies depend, in large measure, on their ability to nurture strong and vigorous scientific communities at home. They have also discovered that, in an increasingly globalized world, science provides an important avenue for international cooperation that enables a nation to have a presence on the world stage. Efforts to promote science-based strategies for solving critical economic and social needs, moreover, have had a positive impact on both society and the scientific community. Indeed as science has proven its worth to society, governments have been increasingly willing to invest in science and, as the impact of science-based development in countries such as China and India have become increasingly recognized, these efforts have emerged as compelling models for other developing nations to follow. TWAS has embraced these trends and, as a result, over the past five years has pursued a number of initiatives designed to emphasize the importance of science-based development. This effort has been reflected in several administrative reforms – for example, the TWAS Council's decision to merge the TWAS awards in basic science and the TWNSO awards in applied science under a single awards scheme and the decision to open TWAS membership to eminent economists and social scientists as part of a larger effort to encourage greater interaction between the natural and social science communities. Other initiatives, pursued in cooperation with the Academy's affiliated organization TWNSO, have led to a series of publications detailing successful applications of science and technology to address such critical issues as access to safe drinking water, the development of alternative energy sources, and the conservation and wise use of indigenous and medicinal plants. These efforts have also resulted in the creation of institutional networks intended to encourage the exchange of information and ideas among organizations that share common interests. The United Nations Development Programme's Special Unit for Technical Cooperation among Developing Countries (UNDP/TCDC), the World Meteorological Organization (WMO) and the Global Environmental Facility (GEF) have all cooperated with TWAS and TWNSO in this effort, a reflection of the widespread interest among international organizations to devise strategies to put science to work to address critical economic and social needs in the developing world.

Sustainability science and science for sustainability. When TWAS was launched in the mid-1980s, the concept of sustainability had yet to be coined – awaiting the publication of the so-called Brundtland Report, *Our Common Future*, produced in 1987 by the World Commission on Environment and Development. Today, while the definition of sustainability remains vague and subject to debate, virtually all observers – including academics, policy makers, corporate managers and grassroots activists – agree on three points: (1)efforts must be made to utilize resources in the most efficient way possible to help ensure that adequate resources are available for future generations; (2)the people of the South deserve to enjoy the same material benefits that the people of the North have enjoyed but that Northern patterns of consumption and production cannot be adopted on a global scale if we are to establish sustainable patterns of growth over the long term (China, for example, is now the world's second largest consumer of oil but on a per-capita basis, the nation consumes just one-tenth of the oil consumed by the United States); (3)science will play a key role in uncovering patterns of resource use and consumption that will allow economic development to take place in the developing world without depleting the global resource base and thus jeopardizing the economic and social well-being of future generations. TWAS has recently focused its attention on the issue of sustainability science, largely through efforts conducted in partnership with the Initiative on Science and Technology for Sustainability (ISTS) at Harvard University's Kennedy School of Government and the Consortium on Science, Technology and

Innovation for Sustainable Development, a joint project of TWAS, ISTS and ICSU. Both groups seek to make science a more critical aspect of sustainable development initiatives by: (1)devising strategies that more closely integrate the natural and social sciences, (2)examining 'place-based' solutions to critical economic, environmental and social issues, and (3)developing programmes that help scientists better understand the economic development community and economic development specialists better understand the world of science. With the concept of sustainability likely to remain at the forefront of policy debates concerning efforts to promote economic development and with science likely to remain a critical tool for achieving this goal, TWAS – as part of its larger efforts to promote scientific capacity building – will continue to pursue partnerships that enable the Academy to provide a strong Southern voice to these discussions.

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TWAS's initial capacity building efforts for science focused directly on the needs of scientists and scientific institutions in the South. In many ways, these efforts have remained at the forefront of the Academy's agenda. Yet, over time, other responsibilities have been added to TWAS's capacity building initiatives. Beyond the Academy's efforts to reward and recognize scientists and to help enhance the capabilities of scientific institutions in the South, TWAS has also engaged in programmes designed to nurture South-South and North-South cooperation, bring science-based solutions to critical economic and social needs in the developing world, and, most recently, enhance the role of science in efforts to promote sustainable development.

Each step that the Academy has taken to expand its mandate has helped to raise its visibility both within and beyond the global scientific community. At the same time, each step has expanded the definition of capacity building in ways that make the term ever-more relevant to the societies in which science operates, not just as a broad set of disciplines designed to shed greater light on the natural world in which we live but also as indispensable tool for making all of our lives – and the lives of children and their children – healthier, happier and more prosperous.

Worlds Apart

In 1999, the world population reached 6 billion. These 6 billion people live in 192 countries that lie across a vast spectrum of development.

Some 30 'developed' countries in the so-called 'North' (mostly Australia, western Europe, Japan and North America) are home to fewer than one billion people – or just 16 per cent of the world population. These people live a desirable quality of life, as reflected through such indicators as economic well-being and access to healthcare.

At the other end of the spectrum, the United Nations Conference on Trade and Development (UNCTAD) recognizes 50 nations, home to more than 1.2 billion people, as the world's least developed countries (LDCs), where the average income is less than US$1 a day.

Spanning these two extremes are about 100 developing nations, where the quality of life is higher than in the LDCs, but far below that achieved in the world's most developed countries.

At the Millennium Summit in September 2000, member states of the United Nations reaffirmed their commitment to working toward a world in which sustainable development and the elimination of poverty would be accorded the highest priorities. Eight Millennium Development Goals (MDGs) were identified and accepted by all 189 members of the UN as a framework for measuring the progress of development. Member states called for most of the goals to be attained by 2015 (*www.un.org/millenniumgoals*), but progress to date suggests that these goals will not be met within this time frame.

Priority areas include: eradicating extreme hunger and poverty; providing universal primary education; promoting gender equality, including disparities in primary an secondary education, and empowering women; reducing child mortality and improving maternal health; combating HIV/AIDS, malaria and other diseases; ensuring environmental sustainability while, at the same time, providing wider access to safe drinking water; and developing a global partnership for development, including systems of open international trade and finance and accelerated debt-relief for the world's poorest countries.

These eight MDGs clearly lay out the destination. What is less clear are the roads that should be taken and the vehicles that should be used to get there. In other words, what are the methods and instruments to be embraced to attain the MDGs?

It is becoming increasingly recognized that understanding the challenges of sustainable development cannot be met without significant increases in the creation and use of scientific knowledge and know-how. Indeed, several recent reports all highlight the importance of interdisciplinary approaches to sustainable development that seek to integrate scientific know-how with strategies for development. Among these are: the *Millennium Project: Interim Report of Task Force 10 on Science, Technology and Innovation* (2004); and *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology* (2004).

The relevance of science and technology to the future of society is more far-reaching today than ever before. It was science and technology that helped India usher in the 'Green Revolution', enabling it to increase its yield of grain fourfold in one generation and thus gain self sufficiency in food. It was science and technology that helped rid the world of smallpox and is helping eradicate polio. And it was science and technology that fuelled the rapid spread of communication and information technologies that have brought the people of the world closer together.

Furthermore, experience in the developed world has shown that science and technology have contributed to individual fulfilment, the well-being of communities and the health of nations. Recent experiences in several developing nations – among them, Brazil, China and India – reinforce this point. Despite evidence of the benefits of maintaining a strong national capacity in science and technology, and national examples of successful science and technology policies, support for science and technology – both in terms of education and practice – remains inadequate for a large part of the world's population.

Levels of proficiency in science and technology vary widely between countries. To determine whether research funds spent by scientists from the wealthiest countries working on collaborative projects across national boundaries are building science and technology capacity in developing countries, a report commissioned by the not-for-profit RAND Corporation and prepared for the World Bank, entitled *Science and Technology Collaboration: Building Capacity in Developing Countries* (2001) compared the science and technology capacity of 150 nations. It classified 22 as scientifically advanced countries (SACs), 24 as scientifically proficient countries (SPCs), another 24 as scientifically developing countries (SDCs) and 80 as scientifically lagging countries (SLCs).

The classification of countries according to their science and technology capabilities does not necessarily reflect their levels of economic development. An economically advanced or developed country (with a high per capita gross national product, GNP) may actually be an SPC, SDC or even an SLC, while another country that is economically 'developing' may be scientifically advanced. For example, the United Arab Emirates with a per capita GNP approaching US$18,000 is classified as scientifically 'lagging' while the

Russian Federation, with a per capita GNP of less than US$2,500, is scientifically 'advanced'. Furthermore, certain developing countries may have high level capabilities in one or more scientific disciplines. The Philippines, for example, is an international leader in rice research, Chile is strong in astronomy, China conducts world class research in seismology, and India is considered among the world's best in mathematics. Such an examination of fields of specialization shows that the ranking of a country, as set out in the RAND report, does not always reflect these pockets of excellence.

It is instructive to examine the factors that have promoted and sustained such excellence, so that these factors can be replicated in more countries and in more disciplines.

Excellence grows out of a variety of factors:

- Government policies to support capacity building.
- International cooperation and support.
- A nation's unique geography, history, traditions, ecology and sociology.
- Networking among scholars.
- Passionate championing by resident or expatriate individuals.
- Scientific role models.

Each of these factors helps build and enhance the science and technology capacity of a nation and thus improve the quality of life and well-being of its people. In this report, we shall present some of the modes through which capacity building in science may be realized.

Technology, too, plays a crucial role in capacity building. However, because of complex issues such as technology transfer, intellectual property rights and private versus public sector ownership, it is difficult to meaningfully cover technological capacity building in this document. Such analysis will have to await a future report.

In addition, over the past decade or so, there have been phenomenal developments in information and communication technologies (ICTs) that have spurred major changes in our lives – in the ways we learn, teach, communicate and even relax. For developing countries to properly advance their scientific and technological capacities – as first steps towards sustainable economic development – ICTs must be made widely available in research institutions and educational facilities in the South; training must be provided for its maintenance and effective use; and ICTs must be fully exploited.

The RAND report classified 80 nations as SLCs – scientifically lagging countries – the lowest bracket. TWAS has a membership of more than 700 Fellows hailing from 80 countries, each of whom has been elected to the Academy on the basis of the excellence of their research. A cross-check of these two lists confirms that more than half of the nations listed as SLCs are also represented by TWAS Fellows. Consequently, there are many SLCs for which TWAS, during its 20-year history, has failed to identify any eminent national scientists. Among these are countries with critical development issues such as Angola, Cambodia and Rwanda.

In addition, the RAND report covers only 150 of the world's 192 countries, and many of those countries not included are on the United Nations Conference on Trade and Development's (UNCTAD) list of LDCs.

TWAS recently set in place a series of programmes designed specifically to help scientists and research institutions in these 50 LDCs, 32 of which are featured on the RAND report's list of SLCs. Among the 18 LDCs excluded from the RAND report are other countries with critical development issues such as Afghanistan, Haiti and Somalia, as well as many small island states that have their own specific development problems.

Taken together, the expertise and diverse nationalities of the TWAS membership, plus the Academy's programmes designed to aid scientists and research programmes in the developing world in general – and the LDCs in particular – gives TWAS both the credibility and the experience to act as 'the voice of science in the South' and lends weight to the conclusions of this report aimed specifically at methods to aid science and technology capacity building in developing countries.

Building and Sustaining Capacity in Science

Problems in the developing world can only be tackled by improving the capacities of both individuals and institutions. While developing capacity requires planning and persistence, sustaining and utilizing it often prove even more difficult. The challenge, therefore, is to develop and maintain a minimum capacity – or critical mass – of highly qualified, innovative scientists and technologists in each country. In addition, developing countries need to build effective science education systems to ensure a continuous supply of scientifically-skilled people. Only when the personnel and inter-related educational system are in place and adequately supported will the world's developing countries have built the 'knowledge foundation' that each country must have to compete in the global economy of the 21st century. Finally, the science community must become more actively involved in policy discussions to ensure that scientific insights and tools become a more integral part of strategies for economic development.

To this end, we propose a development plan for science and technology based on 13 action points, grouped under three major themes: skills development and leadership training, scientific exchange and cooperation, and policy reforms and education.

■ THROUGH SKILLS DEVELOPMENT AND LEADERSHIP TRAINING

1. Centres of Leadership and Excellence

Action Point: *Create and strengthen centres of leadership and excellence, especially in the least developed and scientifically lagging countries, by identifying leading individuals and research teams, providing them with autonomy, financial stability, up-to-date laboratory equipment, access to information technology, and connecting them with their national and international peer groups.*

It is gratifying to note that, despite such problems as the lack of consistent funding and reliable infrastructure, many institutions in the South are carrying out excellent scientific research. The 2003 edition of *Profiles of Institutions for Scientific Exchange and Training in the South*, published by the TWAS-affiliated Third World Network of Scientific Organizations (TWNSO), and the South Centre, for example, lists 525 such institutions from 59 countries.

***Sudan's Camel Clinic**. Among the first recipients of a research grant under TWAS's Science Development Initiative for LDCs was the Camel Disease Research Group at the University of Khartoum's Camel Research Centre, Sudan. The group has used the US$30,000 – which is renewable for an additional two years – to equip a field station in the east of the country, where the nomadic tribes are traditionally found. In the first year, blood samples taken from more than 400 camels confirmed that up to 15 per cent of animals are infected with the blood-living parasite,* Trypanosoma evansi. *Parasitic worms, mites and ticks were also prevalent. In return for being allowed to take blood samples, the researchers used modern drugs to treat the herders' camels. As well as training more students, future plans include identifying how and when the parasites spread, and establishing a series of 'camel treatment centres' along the traditional routes followed by the nomads.*

Some of these institutions compare favourably with the best in developed countries. There are also some that 'plough the lonely furrow' by carrying out excellent work in the 50 nations recognized as the world's least developed countries (LDCs). A total of 43 such institutions are listed in the TWNSO *Profiles of Institutions* book. Scientists and teachers in some of these institutions are role models that inspire students to follow careers in research and development. Many of these individuals and institutions operate under difficult circumstances, yet assisting them with infrastructure improvements, ICT support, or with organizing and attending scientific conferences can often make a significant difference – both to their research output and their ability to reach their nations' policy makers.

Although these countries are the least developed economically, many LDCs are rich in biological resources and traditional knowledge systems, and university scholars in these countries are researching issues of local relevance. Nevertheless, they are hampered in their activities because timely support has not always been available, and sound infrastructure is not guaranteed. Even a small amount of support toward such basic utilities as an uninterrupted power supply, computers and internet connectivity – which gives access to journals on the web and other library facilities – will go a long way to keep their morale high and ensure continuity and success in their work.

Even so, there is an urgent need for the number of qualified scientists and technologists working in LDCs to be increased. This can only be done by supporting and strengthening existing research institutions. New initiatives must be developed to provide special support for these institutions, in particular universities, so that they become centres of leadership and excellence, and are able to produce a steady stream of qualified and enthusiastic young scientists.

Scientists in many countries in the South, particularly LDCs, feel a sense of isolation, which often causes them to leave their home nation, thus adding to the 'brain drain' problem. Such isolation can be significantly alleviated by enabling these scientists to attend professional meetings abroad, and help them interact with their peer group in the 'mainstream' scientific community. The money often required for this purpose is not very great and can easily be allocated by professional scientific societies, national and regional academies of science and development banks. Such help can come in the form of research grants, improved library facilities, easier and more reliable access to information technology and the internet, support for participation in scientific conferences abroad, and exchange fellowships. These programmes help scientists in the developing countries nurture contacts, participate in joint research projects, and receive invitations to write journal articles and book chapters. Bringing once-isolated scientists into the mainstream in this way should also help developing country researchers publish their research in journals with a higher impact factor, and thus increase their visibility – in both the world of science and in the scientists' own countries.

The scale of the problem for LDCs can be seen when it is realized that, of the 710 TWAS Fellows from 81 countries, just 35 (5 percent) are from LDCs. TWAS Fellows from LDCs, moreover, represent only 13 of the 50 LDCs. In addition, of these 35 Fellows, only 20 now live and work in an LDC. In contrast, of the 274 prizes that TWAS has awarded to young scientists over the years (see below), as many as 47 (17 percent) have gone to talented young researchers from LDCs. Many of these prize winners will likely be encouraged to continue their research careers and develop into scientific leaders in their home countries, especially if their efforts are strengthened and they continue to be offered timely support and encouragement.

Awards, prizes and national honours are an effective way of recognizing the worth of individuals, boosting their morale and – since success breeds success – motivating them to do even better. Such awards also bring forth the spirit to compete and achieve. With this in mind TWAS has instituted a variety of award schemes, namely: (i) eight annual TWAS Prizes in Agricultural Sciences, Biology, Chemistry, Earth Sciences, Engineering and Technology, Mathematics, Medical Sciences and Physics; (ii) the Abdus

Malaria Research in Uganda*. Born in Uganda, but trained in Canada and the USA, Thomas Egwang (TWAS Fellow 1997) founded Med Biotech Laboratories (MBL) in his native country in 1995. The institution is unusual in that it is the first non-government-affiliated research laboratory in the country to have been established by a private citizen. With funding from TWAS and the World Health Organization (WHO), MBL has now been responsible for training more than 10 young scientists to MSc and PhD levels in the fields of biotechnology, functional genomics and bioinformatics. Its research into the distribution of insecticide-resistant mosquitoes, the incidence of drug-resistant strains of the malaria parasite and the assessment of candidate vaccines means that MBL scientists are now contributing to the nation's strategy for combating malaria, a disease that kills up to a million people each year, mostly in sub-Saharan Africa.*

***Awards and recognition**. In many developing countries, becoming a successful scientist is no easy matter. For a woman to become a successful scientist is even more difficult. However, Pakistani-born Rabia Hussain has managed to do just that. Having received a master's degree from the University of Karachi in 1969, she earned a doctorate from the University of Western Ontario, Canada, in 1973. After more than 10 years working in the United States, Hussain returned to Pakistan in 1985 where she established an immunology laboratory at the Aga Khan University, Karachi, focusing on diseases relevant to the South, including filariasis, leprosy and tuberculosis. Under her guidance, the laboratory has emerged as one of the pre-eminent institutions in the field in the developing world, and has forged links with the London School of Hygiene and Tropical Medicine, UK, and the Division of Infectious Diseases at Case Western Reserve University, USA. For her achievements, Hussain was awarded the 2000 TWAS Prize in Basic Medical Sciences – which included a cheque for US$10,000 – particularly for her contributions to immunology.*

Salam Medal for Science and Technology; (iii) the TWAS Medal Lectures; and (iv) the TWAS Prizes for Young Scientists in developing countries. Prizes for Young Scientists are offered in collaboration with national and regional academies of science and research councils, illustrating the interest and involvement of these institutions in capacity building efforts.

As highlighted by the lack of TWAS Fellows from the LDCs, a great need exists to identify excellent and proactive individuals and research teams in universities and institutions in these countries that should be offered competitive grants to promote their activities in areas of science and technology of critical importance. If they can be given sufficient autonomy, financial stability and international connectivity, they will perform even better and thus be able to sustain the quality of their research, attract higher calibre students and ensure a continual throughput of young, enthusiastic scientific talent. With timely support in terms of facilities, funds and manpower exchange, these individuals and research groups will emerge to become units of scientific leadership and excellence of particular value in LDCs. TWAS has initiated such a project, providing several grants of up to US$30,000 a year renewable for up to three years. Nevertheless greater long-term support is needed to expand the scope and reach of the project.

***Centre for Scientific Studies**. Among the research institutions funded under the framework of the Millennium Science Initiative (MSI) is the Centro de Estudios Cientificos (CECS, Centre for Scientific Studies) in Valdivia, Chile. Despite being located far from the Chilean capital, Santiago, CECS receives visits from students and scientists from all over the world interested in its specialist fields of biophysics and molecular physiology, glaciology and climate change, and theoretical physics. The institute, which also plays host to several international conferences each year, is headed by Claudio Teitelboim (TWAS Fellow 1991), a renowned expert in quantum black holes physics and the theory of gauge systems. In total, Chile has three ongoing institutes and 14 smaller nuclei participating in the MSI.*

In a similar vein, the creation of 'Millennium Institutes' in chosen areas of science, with the active collaboration of the Science Initiative Group (SIG) and the World Bank, represents an important step forward in North-South collaboration for the purposes of building scientific capacity in the developing world. Funded by the World Bank and guided by SIG at the Princeton Institute for Advanced Study, the Millennium Science Initiative (MSI) has sought to build centres of scientific excellence, first in Latin America and, more recently, in sub-Saharan Africa (*www.msi-sig.org*).

2. Fellowship, Associateship and Training Programmes

Action Point: *Organize fellowships, associateships and training programmes that keep scientists, technologists, technicians and students updated and connected with other centres across the world, so that they become and remain part of the global scientific community, are aware of the latest scientific developments, and have the knowledge and capacity to conduct high-quality research themselves.*

The internet and electronic connectivity have revolutionized communication and the exchange of information. Even so, such tools have their limitations. They are, for example, not a substitute for one-to-one meetings to discuss ideas or work on experiments in the laboratory or the field. Personal interaction helps build mutual trust and confidence, and is important in such areas as learning new laboratory procedures and handling new equipment. In addition, personal interactions often generate information about reference materials and other resources that are not available on the world wide web. In this context, the provision of fellowships, associateships and visiting scientist programmes is a useful and effective way of promoting interaction among scientists.

Many developing countries, particularly LDCs, do not have the facilities for advanced training at the doctoral and postdoctoral levels. Fellowships for postgraduate, doctoral and postdoctoral research programmes thus become

South-South cooperation. *The TWAS-UNESCO Associate Scheme allows scientists from developing countries to pay two visits to participating research institutions in other developing countries during a three-year period. In 2001, Jamal Ibijbijen, professor of microbiology at Moulay University, Meknes, Morocco, was enrolled in the scheme. He has since undertaken two visits, each lasting 3 months, to the National Research Centre for Agrobiology (CNPAB/EMBRAPA) in Rio de Janeiro, Brazil. By enabling more hands-on collaboration with colleagues in Brazil, these visits have led Ibijbijen to expand his research into various soil microorganisms – in particular mycorrhizal fungi and nitrogen fixing bacteria – efforts he hopes will lead to new techniques that can be applied to agriculture in his home country and help increase crop yields.*

an important means for building capacity. TWAS, in collaboration with the International Council for Science (ICSU), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and, more recently, the United Nations University's Institute for Advanced Studies (UNU/IAS) and national agencies (including India's Council of Scientific and Industrial Research, CSIR), has been overseeing South-South fellowship programmes. The South-South aspect of these programmes – whereby scientists from a developing country choose to visit a 'centre of excellence' from the TWNSO *Profiles of Institutions* publication – has a double significance. Not only does it promote South-South collaboration but it helps reverse the 'brain drain' by nurturing a more dynamic and rewarding research environment. As part of a larger effort to promote global science, scientists from both developed and developing countries should be provided with the opportunity to spend time at centres of excellence in the South as associates and senior associates.

In an initiative headed by the Third World Organization for Women in Science (TWOWS), TWAS has assisted the 'Young Women Scientists Fellowship Programme' designed to help female students from sub-Saharan Africa and LDCs. The programme, supported by the Swedish International Development Cooperation Agency's Department for Research Cooperation (Sida-SAREC) has thus far enabled more than 150 young women from 37 countries to pursue postgraduate degrees at centres of excellence in the South located in countries other than their own. In addition, TWAS has proposed a new initiative for the creation of senior associateships that would enable senior scientists from developing countries to spend time at centres of excellence in the South.

Apart from research programmes, there is a need to train technicians and engineers in trouble-shooting, maintaining, and upgrading scientific equipment in use in laboratories in the South. Such technical training programmes should operate in several ways: through purchase-time agreements with manufacturers for the training of technicians in user

TWOWS first graduate. *In July 2002, Aderoju Osowole became the first student to graduate from the TWOWS Young Women Scientists Fellowship Programme. Having gained her bachelor's and master's degrees from the University of Ibadan in her native Nigeria, she enrolled in the same institution for her PhD studies. Unfortunately, the equipment she needed was not available at the University of Ibadan. An application to TWOWS was successful, and Osowole was able to spend a year at the Indian Institute of Science's Department of Inorganic and Physical Chemistry in Bangalore, India. "At Bangalore I was able to carry out the microanalysis and infrared and mass spectroscopies that I needed to complete my PhD research on the physico-chemical properties that exist between metal ions and certain organic molecules," confirmed Osowole. She is now back in Nigeria where she is not only continuing her research, but also imparting her valuable experience and knowledge to other graduate and postgraduate students.*

Delivering science to the South*. Launched in autumn 2001 by TWAS and the Abdus Salam International Centre for Theoretical Physics (ICTP), the eJournals Delivery Service now has nearly 400 subscribers from over 60 developing countries. Subscribers can access more than 240 journals provided by such publishers as the Academic Press, the American Physical Society, the Optical Society of America and the World Scientific Publishing Company. In addition, last year, Elsevier Science, one of the world's largest and most prestigious scientific publishing houses, agreed to provide scientists in the South electronic access to its complete list of physics and mathematics journals. The aim of the ICTP/TWAS eJournals Delivery Service is to distribute individual scientific articles via email to scientists in institutions throughout the Third World that do not have access to sufficient bandwidth to download material from the internet in a timely manner and/or cannot afford the connection costs. In this way, scientists are provided with up-to-the-minute literature to support their ongoing research. For additional information, see* www.ejds.org.

countries; arrangements with centres of excellence in the South for technician exchange and training; and the organization of periodic workshops for technicians, including virtual classes provided via the internet.

In many laboratories and hospitals in developing countries, a minor failure can mean that equipment lies idle and work is interrupted for extended periods. Disabled machines could easily be made operational if the necessary spare parts were available. To help overcome such problems, TWAS has been operating a programme of small grants for the provision of spare parts since 1986. So far, more than 400 spare parts have been purchased and sent to institutions in some 50 developing countries (11 of them LDCs). Likewise, TWAS, in collaboration with the Abdus Salam International Centre for Theoretical Physics (ICTP), has been operating a donation programme for science books and journals. More recently, TWAS and ICTP have launched an eJournals Delivery Service designed to take advantage of the ready access to information, particularly scientific papers, provided by new electronic and communication technologies. With sufficient funding, technical training and skill-updating could easily be added to these existing schemes.

■ THROUGH SCIENTIFIC EXCHANGE AND COOPERATION

3. Scientific and Technical Cooperation in the South

Action Point: *Promote scientific and technical cooperation in the South through South-South fellowships for postgraduate and postdoctoral researchers, the exchange of scholars and, in particular, persuade the more scientifically proficient and technologically advanced developing countries to make significant contributions towards the development of the less fortunate.*

Developing nations cover a broad spectrum of capabilities in science and technology. Countries such as Brazil, China and India have established well-run institutions, many of which are world-class, and now enjoy extensive facilities for research and training. It has thus become possible for these nations to help other developing countries through South-South cooperation initiatives.

Such South-South programmes should prove extremely fruitful since participants are sensitive to the bureaucratic, economic and cultural conditions prevalent in each others' nations. The programmes become even more meaningful and effective when they address issues of common concern to neighbouring countries.

Some positive steps have already been taken. Brazil, for example, has created a programme to provide scientific assistance to Portuguese-speaking nations in Africa. The Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India, provides postgraduate and postdoctoral training programmes for scientists from several countries in the South, and the Indian

South-South fellowships*. TWAS has entered into agreements with governments and institutions in several countries and now offers fellowships to young scientists to carry out research in a country other than their own for periods ranging from 3 months to a year. They are then encouraged to return to their home countries to continue their careers. In particular, in collaboration with India's Council of Scientific and Industrial Research, TWAS offers both postgraduate and postdoctoral fellowships in a variety of fields. In addition, the Indian government, under the auspices of the Department of Biotechnology, now offers 50 biotechnology fellowships each year. The programme is administered in collaboration with the International Centre for Genetic Engineering and Biotechnology (ICGEB), which has centres in Trieste, Italy, and New Delhi, India. A similar agreement has been reached with the government of Brazil through its Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazilian National Research Council), which is providing an additional 50 postgraduate and postdoctoral fellowships. The government of China, through the Chinese Academy of Sciences (CAS), has also recently joined the TWAS-administered South-South cooperation programme, offering 50 fellowships each year to postgraduate students, postdoctoral researchers and visiting scholars.*

National Science Academy has bilateral programmes for the exchange of scientists and training of students with academies of science from more than more than 10 countries.

In addition, India's Council of Scientific and Industrial Research (CSIR) cooperates with TWAS to offer fellowships to Third World scientists and students, and the Department of Biotechnology, India, has agreed to do the same in its area of specialization. In addition, from 2004, the governments of Brazil and China have agreed to sponsor 50 fellowships a year for young researchers from other developing countries to work in their laboratories. These exchange programmes will be managed by TWAS.

The First South Summit, sponsored by the Group of 77 (G-77, an association of developing countries within the United Nations), held in 1999 at Havana, Cuba, called for the creation of a trust fund to promote science and technology capacities in the South. A similar fund, established 20 years ago by the African Technical Cooperation Agency (ATCA), part of the African Development Bank, for example, now generates up to US$25 million per year. TWAS should seek to persuade the World Bank, regional development banks, international donor agencies and relevant UN organizations to contribute to such funds and find ways to allow them to operate effectively.

4. Institutional Networks to Address Common Problems

Action Point: *Create networks of institutions to address common problems relating to issues of regional concern or common interest such as water, the environment and sustainable development, through joint symposia and research projects, and promote interactive networks using the latest communication technologies.*

Critical issues of common regional concern in the South include the provision of safe drinking water; agriculture and food security; the spread of such diseases as malaria and AIDS; environmental problems such as deforestation and desertification; and efforts to promote sustainable development.

The programmes described above are useful in addressing such issues. However, more can be done to allow institutions in developing countries to form networks to tackle common problems. Such South-South networking programmes have been shown to be excellent vehicles in addressing these issues and finding generalized as well as locally relevant solutions.

A successful example of multilateral South-South collaboration has been the efforts of Kenya, Uganda and Tanzania in the Lake Victoria Environmental Management Project, aided by funding from the Global Environment Facility

(GEF). The five-year project that began in 1997 is now well on the way to rehabilitating the lake, which provides resources for more than 25 million people, but which was becoming severely polluted, overfished and invaded by the aquatic weed, the water hyacinth, which interferes with fishing operations, serves as a breeding ground for malaria-transmitting mosquitoes and clogs up the water intake of a hydropower plant.

Now, industrial and municipal discharges into the lake are being curbed, populations of the major commercial fish species have been measured and quotas set, and the area covered by the water hyacinth has been reduced by more than 80 percent. (As a side project, Sida, the Swedish International Development Cooperation Agency, and LAVISCA, a nongovernmental organization, invited school children to help with the project and learn about road building, the use of traditional building materials, and how to make biogas out of the water hyacinth – an excellent example of how to introduce children to the benefits of science and technology).

Apart from efforts to solve problems, such South-South collaborative efforts also help build capacity through mutual assistance. It is in this spirit that joint symposia and research projects should be initiated between countries that share common problems or natural resources. Such efforts should start at the level of symposia where issues of mutual concern can be defined. Based on these discussions, joint research programmes should be initiated involving the exchange of scientists, technologists and students. Programmes should also be designed to bring together diverse, cross-disciplinary ideas and experimental approaches that are mutually enhancing. In this way, the efforts will not just promote capacity building, but help scientists and policy makers understand common problems, cooperate on developing common solutions to them, and perhaps even resolve regional conflicts through the application of science and technology.

One noteworthy example in this regard, is the wide-ranging effort of the Third World Network of Scientific Organizations (TWNSO) and the United Nations Development Programme Special Unit for Technical Cooperation among

Networking. *In collaboration with UNDP/TCDC and TWNSO, TWAS has developed a network of institutions in the South with special expertise in medicinal plants. Two workshops have been organized, one held in Karachi, Pakistan, and the other in Trieste, Italy, each of which was attended by more than 20 scientists from the developing world. As a result of these workshops, two books of case studies have been published. These case studies describe successful initiatives initiated by institutions in the South that have begun to use their native flora to promote healthcare and even provide much-needed revenue through the development of commercial pharmaceutical products. In addition to the workshops, a regular newsletter is circulated among participating organizations, allowing scientists to keep up-to-date with each other's work and other developments in the field.*

Developing Countries (UNDP/TCDC) to help institutions in the South form networks in the areas of dryland biodiversity (also supported by the Global Environment Facility, GEF), fresh water management (also supported by the World Meteorological Organization, WMO), renewable energy, and medicinal plants.

Indeed, these issues cover the five main areas highlighted by UN secretary general Kofi Annan in his speech prior to the World Summit on Sustainable Development held in Johannesburg, South Africa, in 2002, as being critical for sustainable development: water, the environment, health, agriculture and biodiversity (commonly referred to as 'WEHAB'). In particular, TWNSO has helped launch an e-newsletter for Third World scientists interested in developing pharmaceutical products from medicinal plants. The newsletter was initially sent only to delegates that attended a workshop in Trieste, but it is now being distributed to researchers throughout the South, helping them stay in touch with the latest news and developments in this specialized field.

5. Innovative and Successful Experiences

***Action Point:** Share successful experiences to foster the involvement of scientists and planners in the use of science for national development. Despite the difficult odds, there are creative, home-grown ways to address and solve critical development issues.*

Success breeds success. One story of a triumphant initiative can motivate others to replicate its methods and perhaps succeed where previous efforts to solve a problem had failed. Sharing successful efforts through the publication of case studies, therefore, can help build capacity by building knowledge and confidence. Such case studies also tell the South that despite its 'developing' label, it can succeed using scientific methodologies, even with moderate resources. There are many success stories drawn from the experiences of individual countries in the South and from South-South collaboration. The efforts of Kenya, Uganda and Tanzania in tackling the environmental problems of Lake Victoria, as mentioned in section 4, and the collaboration between Brazil and China to build and launch Earth-monitoring satellites, are just two examples.

Some of these efforts pay quick dividends while others take time to show their effects. One such successful initiative that should be highlighted is the success of India's application of science and technology to transform the country from being a net importer of food to a net exporter within a matter of 20 years. As another example, in the 1960s, when India began to invest in engineering and technology institutes, it did not anticipate reaping immediate benefits. In fact, by the time the information and communication technology

***Innovative experiences**. A series of workshops sponsored by TWAS, TWNSO and the Global Environment Facility (GEF) resulted in a book, published by Kluwer Academic Publishers, The Netherlands, of more than 30 case studies on the theme of:* Conserving Biodiversity in Arid Regions: Best Practices in Developing Nations*. The TWNSO-organized workshops were held in Chile, Egypt, Mongolia and Oman, and were attended by some 200 scientists. Among the case studies presented – which are all dedicated exclusively to activities in the South – are best practices for managing vicuña populations in Peru, preventing coastal erosion in Oman, restoring Mongolia's Lake Baikal basin, and conserving forests in Burkina Faso.*

(ICT) revolution arrived in the 1980s, India was fortunate in that it already had a significant number of trained students eager and capable of learning and mastering the intricacies of ICTs. Today, India ranks among the world's top nations in ICT, with many home-grown ICT companies competing on the international market. Likewise, China now has a large workforce trained in biotechnology and is rapidly becoming a world leader in agricultural applications of this new field. There are similar examples from many other countries in the South.

In cooperation with the UNDP/TCDC and other UN-based agencies, TWNSO has sought to promote the sharing of such innovative and successful experiences. To date, as outlined in section 4, TWNSO has organized nine workshops broadly based on the WEHAB themes, including safe drinking water, sustainable use of dryland biodiversity, renewable energy technology and its applications, and medicinal plants. The workshops, attended by scientists from the South, have resulted in the publication of five volumes containing more than 60 case studies written for a non-technical audience – including policy makers – as well as a collection of scientific papers, printed by Kluwer Academic Publishers, that includes more than 30 reports from throughout the South. Among the successful initiatives reported in these volumes are: the development of traditional herbal remedies for use against diabetes; the creation of seed banks to help farmers restore diversity and rely less on monocultures; water-harvesting systems; tillage methods to prevent soil erosion; and a small-scale hydroelectric power generator that can be used in virtually any source of running water to provide power to a few homes or businesses.

Publication of these successful initiatives means that they can serve as references for scientists and technologists for planning cooperative efforts, and as guides for decision makers, particularly government ministers and planning bodies, that can be alerted to the ability of science and technology to address critical development issues. The free dissemination of the case study publications in the TWAS-TWNSO-UNDP/TCDC 'Sharing Innovative Experiences' series also helps scientists in the South discover new lines of research and come into contact with other researchers interested in similar issues, thus enlarging the circle of cooperation.

6. Interdisciplinary Panels of Experts in the South

Action Point: *Organize South science summits that bring together interdisciplinary panels of experts – in science and other areas critical to development issues – aimed at persuading national leaders in the South to place science and technology (S&T) at the top of their political agenda, so that S&T become integral parts of their development programmes.*

It has become increasingly evident that the only way to address and solve problems of development and to increase the gross domestic product (GDP) of a nation is through the home-grown development and use of science and technology. It has also become clear that regional issues concerning the environment, agriculture and sustainable development are best handled through the cooperative participation of the nations concerned. It is thus important to mobilize leaders in the South to place science and technology at the top of their political agendas, so that they become integral parts – indeed fundamental instruments – of overall programmes for economic and social development.

'Science Summits' convened by academies of science and similar bodies can generate local and international support for science development in the South. The Lake Victoria Environmental Management Project, mentioned earlier, is a good example of how a science summit can help identify a problem and the methodologies that should be used to achieve a solution. Project implementation has led to a significant increase in the populations of fish and other aquatic life in the lake, resulting in economic and social benefits for the region's people.

The establishment of institutions such as the Research and Development Forum for Science-Led Development in Africa (RANDFORUM) and the Commission on Science and Technology for Sustainable Development in the South (COMSATS) has been pertinent and useful in this connection. These organizations link together scientists, technologists, entrepreneurs and governments, and organize meetings designed to generate ideas and programmes for assisting national development through the use of science and technology.

RANDFORUM, established in 1992, now includes some 40 African nations as members and organizes events where government ministers and scientists meet to discuss issues of common concern. In addition, RANDFORUM has created the African Foundation for Research (AFRAND) fund, aimed at supporting programmes that put into practice new technologies and social services that directly address Africa's problems. One such example is its *Sourcebook on African Food Production and Processing Technologies for Commercialization*, published in 1996 with help from the UNDP/TCDC. The book aims to help African entrepreneurs interested in investing in appropriate

TWAS general meetings. *Since its inception in 1983, TWAS has brought its members together at general meetings and conferences held mostly in developing countries. The first to be convened outside Italy was the second General Conference held in Beijing, China, in 1987 which was hosted by the Chinese Academy of Sciences. Since then, meetings were held in Venezuela, Kuwait, Nigeria, Brazil, Senegal, Iran, India and – coming full circle – China once more in 2003. As well as focusing on the scientific achievements of the host nation, the meetings are used to honour scientists from throughout the South with TWAS Medals and Prizes. The meetings are designed to coincide with those of TWNSO, which ensure the presence of ministers of science from several developing countries – thus helping to highlight both the achievements and benefits of science to a wider audience. This combination of policy makers and scientists also provides a unique forum for discussions on capacity building for science in developing countries.*

indigenous food production and processing technologies. Another programme is aimed at persuading expatriate Africans to become involved in Africa's development by channelling their talents and skills towards relevant issues. (Some 20,000 highly skilled Africans leave the continent each year). And a third programme is designed to help re-integrate science and technology into African culture – and indigenous knowledge into modern science and technology – in the wake of centuries of colonial rule that divided and isolated these two complementary knowledge systems.

COMSATS, established in 1994, has concentrated on bringing information technology to its 35 member states across Africa and Asia. For example, it has organized periodic summits on such subjects as the isotope hydrological assessment of groundwater resources (held in Iran) and biotechnology (held in Lebanon). Such initiatives are geared towards involving policy planners and government ministers and thus seek to pave the way for having science serve as a vehicle for national progress and international understanding. COMSATS has also established an information technology centre in Damascus, Syria, and has identified 13 centres of scientific excellence in countries throughout the South that can be used as 'hubs' for reaching out to scientists and policy makers in neighbouring countries.

7. Merit-based Science Academies in the South

Action Point: *Promote merit-based science academies in the South to help promote and sustain scholarship, act as guardians of ethical values in science, serve as role models for the young, recognize and reward research excellence, interact with other academies and scholastic bodies, and engage governments in matters where science and policy meet.*

National academies of science represent an effective forum for building scientific capacity and leadership. Academies should be merit-based and the election of members should be transparent and decided on the basis of proven scientific excellence. Only then will academies have independent scholastic standing and enjoy esteem and respect among peers and policy makers alike.

An academy of science has multiple responsibilities: to promote and sustain scholarship; to be the guardian of ethical values in science; to serve as a role model for youngsters, including the promotion of science as an interesting and rewarding career; to popularize science and its achievements; to recognize and reward excellence in scientific research, including the honouring of scientists through prize and award schemes; to interact with other academies and scholastic bodies within the country and abroad; and to serve as the voice of science for the nation and engage governments in matters where science and policy meet, especially issues related to national development.

While many countries in the South do have national academies of science, they are lacking in many African countries. In fact, although the continent has 53 countries, it is host to only nine national academies and the African Academy of Sciences. This inadequacy needs to be corrected. The InterAcademy Panel on International Issues (IAP) – an organization affiliated to TWAS and also based in Trieste, Italy – has embarked on a capacity building project for academies. Workshops have been held in Islamabad, Nairobi, Rio de Janeiro and Trieste. Among the successful outcomes of these meetings have been the creation of the Network of African Science Academies (NASAC) in 2001, and the Network of Academies of Sciences in Islamic Countries (NASIC) and the InterAmerican Network of Academies of Sciences (IANAS) in 2004. These networks provide a framework for strengthening regional activities to tackle regional problems, to assist each other and especially weaker academies in the region, and to support the creation of viable academies in neighbouring countries where they are

Working together: The world's academies of science. *The InterAcademy Panel on International Issues (IAP) was launched in 1993. In 2000, its secretariat moved to Trieste, Italy. It currently counts more than 90 of the world's merit-based academies of science as members. Since its inception, IAP has issued statements on population (1994), urban development (1996), sustainability (2000) and human reproductive cloning (2003). In addition, at its 2003 General Assembly, held in Mexico and hosted by the Mexican Academy of Sciences, five statements were launched focusing on health of mothers and children, science capacity building, science education, science and the media, and access to scientific information. IAP also runs a series of programmes, each headed by a lead academy, including capacity building for young academies (for which TWAS takes the lead), science education, and science and the media. In 2004, IAP decided that all but this last programme would continue, and that the health of mothers and children programme would be re-launched as health education of women. In addition, a new programme on water research and management has been initiated.*

lacking. Through such networks and the creation of new academies, science can find a voice in many developing countries and – supported by these nations' top scientists – push for change from within.

8. Tapping Global Brain Power

***Action Point:** Mobilize expatriates and institutions in the North so that the 'brain drain' can be converted, in part, into a 'brain gain'; encourage scientists in the North to work on major Third World problems and assist in building scientific capacity and research excellence in the South.*

Many Third World countries invest valuable resources in training scientists who then leave to make their careers in the North – a phenomenon known as the 'brain drain'. Some countries, such as Singapore and China (including Taiwan), have addressed this issue by investing significant sums of money to create world-class scientific institutions and providing salaries and infrastructure to entice expatriates to return and continue their careers at home. However, because of the financial resources and political will required, such countries are still few and far between. Other methods have been tried to engage expatriates in helping to build scientific capacity in their homelands. Initiatives by the United Nations Development Programme (UNDP), through its 'Transfer of Know-how and Technology through Expatriate Nationals' (TOKTEN) programme, have had some success. Such programmes, which draw on deep-seated cultural heritage and societal ties, are an effective way of building capacity and should be more fully supported so they can be implemented on a wider scale.

Visiting scientist programmes are another useful means of building scientific capacity. Properly designed, they provide institutions in the South, especially those with limited outside contacts, with the opportunity to establish long-term links with world leaders in science, particularly those working in the

***AIMS for Africa.** The African Institute for Mathematical Sciences (AIMS) was established in Cape Town, South Africa, with the goal of strengthening scientific and technological capacity across the continent. AIMS is a collaborative project between three South African universities, Cape Town, Stellenbosch and the Western Cape, as well as the University of Cambridge, UK, the University of Oxford, UK, and the University of Paris-Sud-XI, France. AIMS will initially focus on a one-year postgraduate diploma course designed to develop strong mathematical and computing problem-solving skills. Courses, which include quantum physics, epidemiological modelling and financial mathematics, will be taught by eminent lecturers from Africa, the three collaborating European universities and elsewhere. Students with degrees in mathematics, science or engineering are recruited from across Africa. Its first course, which began in September 2003, received over 80 applications, 30 of which – representing students from 15 countries – were successful. For additional information, see www.aimsforafrica.org.*

Helping out back home. *Born in Iran, Hamid R. Habibi was educated in the UK and Canada, where he has lived for the past 20 years. He is now a distinguished member of the University of Calgary's Department of Biological Sciences. Under what is now the TWAS-ICSU-UNESCO-UNU/IAS Visiting Scientist Programme, Habibi visited Iran in both 2000 and 2001, using the experience gained in his well-equipped laboratory in Canada to help develop the research capacity in his home nation. In particular, he has been able to develop collaborative research with Mohammad H. Sanati of the Iranian National Research Centre for Genetic Engineering and Biotechnology. Both scientists have an interest in gonadotropin-releasing hormones in mammals and fish. Such studies have proven useful in addressing a variety of public health and environmental concerns, ranging from treatments for prostate and breast cancers – which are all-too-common in Iran – and efforts to increase fish stocks in aquaculture facilities and to protect the threatened sturgeon – the source of caviar – one of Iran's most valuable natural resources.*

North and other scientifically advanced countries.

Such programmes should involve both expatriate nationals and foreign scholars who can interact closely with faculty and students at the host country institution, as part of a larger effort to strengthen existing activities and establish new lines of research. When they involve expatriate nationals, such programmes become ways to offset the 'brain drain' and instead use visiting scientists as a 'brain gain'. This scheme can also encourage scientists and institutions in the North to work on major Third World problems. TWAS, in collaboration with ICSU, UNESCO and UNU/IAS runs such a visiting scientist programme, but again the resources are meagre compared with the challenges that are faced.

9. Information and Communication Technologies

Action Point: *Provide equitable access to currently available knowledge, create virtual networks among teams of research scientists working in different countries, and promote advanced wireless digital communication systems that are most relevant to developing countries.*

With the widespread use of personal computers and the advent of the internet, the practice of gathering, storing, using and transmitting data has changed dramatically over the past 20 years. Thanks to the world wide web and electronic mail, people around the world can now communicate at the push of a button, and geographical boundaries no longer remain barriers for the exchange of knowledge. The cost of obtaining a high performance computer workstation for multiple user access with an uninterrupted power supply, internet connection, email facility and on-line access to journals and databases is now equivalent to the cost of a high quality motorcar – less than US$50,000. This has made information and communication technologies (ICTs) available to many colleges, universities and research centres in developing countries. Whereas scientists in the South may previously have never heard of recent publications relevant to their work – and even if they had, they would have had to wait weeks until a reprint was mailed to them – this information can now be accessed instantly from the desktop.

This ICT revolution provides a remarkable opportunity for research institutions in the South to 'leapfrog' into the information age and to update their capabilities not only in science and technology, but in other areas of daily life as well. In this connection, the World Summit on the Information Society (WSIS) – the first phase of which was held in Geneva, Switzerland, in December 2003 and the second phase of which will be held in Tunis, Tunisia, in November 2005 – has proposed an agenda for action that will go a long way to help build capacity in science and technology in developing countries. During the meeting in Geneva, TWAS, together with the European Organization for Nuclear Research (CERN), ICTP and UNESCO, proposed the following items, all of which were adopted in the WSIS Declaration of Principles and Action Plan.

- Ensure that all universities and research institutions have affordable and reliable high-speed internet connections to support the critical role that such connections play in information and knowledge production, education and training.
- Encourage initiatives to increase scientific literacy and awareness of how to interpret web-based scientific information.
- Promote sustainable capacity building and education initiatives to ensure that all countries benefit from the new opportunities afforded by ICTs for the production and sharing of scientific information and data.
- Ensure that legislation dealing with database protection guarantees full and open access to data created with public funding. In addition, restrictions on proprietary data should be designed to maximize their availability for academic research and teaching purposes.

TWAS and the World Summit on the Information Society (WSIS). *TWAS and a consortium of other international science organization, including CERN, ICSU, ICTP and UNESCO, have developed a series of proposals which have been included in the Declaration of Principles and Action Plan signed during the first phase of the WSIS held in Geneva, Switzerland, in December 2003. In the run-up to the second phase of the summit, to be held in Tunis, Tunisia, in November 2005, TWAS and its partners are organizing a satellite summit, 'Past, Present and Future', which will highlight the role of scientific knowledge and research in the information society and emphasize the problems, possibilities and successes of research institutions in developing countries.*

- Promote electronic publishing, differential pricing schemes, and appropriate open source initiatives to make scientific information accessible on an equitable basis.
- Support urgently needed research on the use of information technologies in key areas such as geographical information systems, climate conditions and telemedicine, and on the socio-economic value of public domain information and open access systems.
- Recognize the important role of science in developing and implementing the new governance mechanisms that are necessary in the information society – for example, internet security and next-generation technical issues.

Under this scenario, it should be possible to provide equitable access to currently available knowledge, create virtual networks among teams of research scientists working in different countries, and promote advanced wireless digital communication systems that are most relevant to developing countries, avoiding costly wired networks.

For most developed countries, economic success no longer relies on industrial production but on the creation, acquisition and utilization of 'knowledge'. By improving ICT infrastructure – and access to it – in the developing world, countries in the South will have the opportunity to participate fully in the new global 'knowledge economy', without first having taken the industrialization route followed by so many countries in the North.

Simply put, the importance of ICTs to developing scientific and technological capacity in the South cannot be understated. Properly implemented, such technology – and its applications in education, scientific research, business and the wider community – can bring Third World countries rapidly into the 21st century.

■ THROUGH POLICY REFORMS AND EDUCATION

10. Educational Systems

***Action Point:** Reform educational systems so that every citizen benefits from a knowledge of general science and bright students are motivated to pursue careers in science. This should involve both national and international collaborative efforts aimed at both students and teachers, and make full use of developments in information and communication technologies.*

A general knowledge of science and an understanding of scientific principles helps people make rational decisions in their everyday lives – based on fact rather than intuition or 'pseudoscience'. It is vital, therefore, that the message of science reaches everyone in developing countries – young and old, men and women, and literate and illiterate. To this end, science education must begin in primary schools. At the primary/middle school level, the main challenge is to deliver the core message of science for children – making lessons entertaining while teaching children how to apply the scientific method. At the secondary and tertiary/university levels, the challenge is to find ways of imparting the essential and crucial knowledge of a subject and to motivate bright students to pursue careers in science.

We contend that an international cooperative programme should be organized in consultation with participating national governments and academies of science to improve science education in schools and in adult literacy programmes. Such a programme should collect and disseminate tried and tested science curricula and, through an international network, transfer them to all countries. A set of standards should be agreed upon, outlining what children should know and understand at the end of each year of schooling. Core concepts should be identified and teaching materials and classroom experiences listed and recommended. The same material could also be adapted for adult literacy programmes.

In addition, a network should be created through which individual experiences, success stories and curricular material can be shared. It is noteworthy that the Massachusetts Institute of Technology has put much of its instructional course material on the internet (*web.mit.edu*). Some biology textbooks (including examination questions, with answers) are now freely available on the internet and can be downloaded for personal use. Use of ICTs and audiovisual media (radio, television and video) should be encouraged from the earliest levels. Universal access to personal computers should also be encouraged. It is important that science at school and university levels be considered an international movement and, as such, implemented through national and regional programmes associated with

***Science education for all**. The InterAcademy Panel on International Issues (IAP), a TWAS-affiliated organization which also has its secretariat based in Trieste, Italy, runs a science education programme, headed by the Chilean Academy of Sciences. Through the programme, IAP seeks to reform science education on a global scale by encouraging hands-on inquiry-based learning, especially in primary and secondary schools. In addition, an interactive electronic portal has been created in collaboration with the International Council for Science (ICSU) highlighting national curricula in science education (ICSU/IAP Teaching Science Portal:* http://www.icsu.org/1_icsuinscience/CAPA_TeachSci_1.html*).*

international scientific associations. To this end, international and regional centres for science education should be established to initiate and coordinate these action programmes.

Refresher courses and continuing education programmes also need to be developed to help teachers stay abreast of current scientific advances and teaching practices. Steps must be taken to recognize and reward excellent teachers, since they are vital as role models and guides to students in choosing their careers. The isolation of teachers in developing countries is a factor that adversely affects their effectiveness. Various practices, including cooperative activities organized by regional teacher associations, can be put in place to minimize this isolation. Some effective examples of engaging teachers and updating their knowledge and skills are the *Inspire* (Innovative Scheme for Post-docs in Research and Education) programme of Imperial College, London, United Kingdom (*www.ic.ac.uk/inspire*), and the Indian Academy of Sciences' journal of science education, *Resonance*, which solicits and receives popular science articles from teachers aimed at the high school and undergraduate levels (*www.ias.ac.in/resonance*). The Indian Academy of Sciences also involves teachers by regularly inviting them to special sessions at its annual meetings.

11. Science and the Public

***Action Point:** Science for all is a conviction that should motivate governments, voluntary organizations, educators and scientists alike to ensure that the message of science reaches every human being, including policy makers and politicians.*

The relevance of science and technology to the future of society today is more far-reaching than ever before. Solutions based on science and technology can provide remedial measures to many of our problems, yet a vast proportion of the world population lacks a basic understanding of science and technology. Past experience in the developed world has shown that science and technology have contributed to individual fulfilment, the well-being of

> ***Popularizing science**. TWAS actively promoted the creation of SciDev.net – an internet portal that allows access to scientific news items of interest to countries in the South – items that are often available only through subscriptions to journals such as Science and Nature. Weekly additions to the website, including links to general scientific articles as well as articles on science policy issues published by an increasing number of collaborating partners, including BBC Online and New Scientist magazine, are freely available to internet users worldwide. SciDev.net is funded by the UK Department for International Development (DFID), the Swedish International Development Cooperation Agency (Sida), the International Development Research Centre (IDRC), Canada, and the Rockefeller Foundation, USA.*

communities and the health of nations. The experience of many developing nations reiterates this point. It was science and technology that helped India usher in the 'Green Revolution' by increasing its food grain output fourfold in a generation, enabling India to gain self-sufficiency in food production. It was science and technology that helped the world rid itself of smallpox and has helped push polio to the verge of eradication. It was science and technology that helped build and launch the many satellites that are being used to monitor the Earth's surface for the purposes of improving weather forecasts and environmental management. And it was science and technology that fuelled both the recent air transport boom and the rapid spread of information and communication technologies that have brought the people of the world closer together. Thus science and technology, when judiciously applied, can provide the way for achieving the United Nations' Millennium Development Goals.

For science and technology to be used wisely and effectively, everyone – children and adults, the educated and the illiterate, the public, politicians and policy makers – must have an appreciation of science and its power to transform the quality of life. The excitement of practicing science must be transmitted to school children through audiovisual media and by offering them hands-on experience in schools and community science centres. Low cost science kits, as well as those that can be easily assembled using locally available materials, must be made more widely available. Thanks to the efforts of many science educators around the world, there exists a wealth of information on such kits. This information should be made available on the internet, in newsletters and through other modes of communication. Invariably, when children experience science, they become interested and may well decide to pursue scientific careers.

For the public too, an appreciation of science is important, because they are the ones who will have an important say on whether – and how – the products of science will be used in society at large. Unfounded fear of the unknown and a sense of bewilderment are the usual causes given for the rejection of new scientific advancements or technologies. It needs to be reiterated that science helped foster solutions to food security issues (through the Green Revolution), the eradication of diseases, instant communication between people across the globe, and ways and means to address critical environmental problems.

Education and knowledge-enrichment programmes in the media, and direct dialogue and interaction between scientists and the public are vital so that the science, its power and its limitations become more widely understood. Science appreciation initiatives should be organized by scientific organizations, universities and academies of science on a regular basis. Voluntary organizations and governments should ensure that literacy movements directed towards adults also include scientific literacy as a major component.

It is equally important for policy makers and parliamentarians to be aware of developments in science and technology, and how these can be used for societal benefit. It is here that national, regional and international academies of science, science advisory committees to governments and similar bodies should play a leading role. Regular sessions between scientists and government officials, ministers and legislators can help in sensitizing the latter groups to the latest advances in science and how these can be used to solve development problems.

Targeting the press. *Despite a lack of understanding of the basic science, many people are interested in a range of scientific issues and the ethical dilemmas they pose. To coincide with United Nations' discussions on the biotechnological advances that have raised the possibility of producing cloned human beings, the InterAcademy Panel on International Issues (IAP) released a 'Statement on Human Cloning' that supported a ban on human cloning for reproductive purposes but argued that cloning for therapeutic purposes should be allowed. Near-simultaneous press releases in Trieste (Italy), London (UK) and São Paulo (Brazil) ensured worldwide media coverage and highlighted not only the ethical issues, but also the science behind the cloning debate.*

12. The Private and Nongovernmental Sectors

Action Point: *Engage the private and nongovernmental sectors as agents for national development by supporting science and technology through in-house and out-sourced research, training, recruitment and related modes of support. Governments can also implement 'push' and 'pull' mechanisms – such as tax breaks and levies – for private companies to encourage them to invest in research and development.*

The private sector and nongovernmental organizations (NGOs) in the South are only just beginning to become involved in capacity building efforts. There are some outstanding examples of such involvement, such as the Aga Khan

> ***Gates' grant***. *The US-based Bill and Melinda Gates Foundation has awarded a US$20 million grant to the US National Academy of Sciences to help academies of science in Africa. The money, which will be provided over a ten-year period, will be used to help key African science academies play a more prominent role in the political arena, enhancing their ability to influence governments by, for example, publishing in-depth expert reviews on key issues of social concern.*

Foundation in Pakistan, and the Tatas in India, both of which have financed the creation of universities and educational institutions. There is also the Domingo Liotta and Fortabat Foundations in Argentina, the *Grupo de Institutos, Fundações e Empresas* (GIFE) in Brazil and the *Fundación Esquel* in Ecuador that help individuals and institutions prepare research grants. Such initiatives should be expanded and strengthened. Other agencies such as Worldwide Initiatives for Grantmaker Support (WINGS, *www.wingsweb.org*) are useful in offering help with resources, names and descriptions of non-profit entrepreneurs and foundations, and sources of grants for internship programmes. Some of these efforts take place in collaboration with major philanthropic institutions in the North, including the Fulbright Foundation, Rockefeller Foundation, W.M. Keck Foundation and Bill and Melinda Gates Foundation.

The private sector has also successfully engaged itself in education, research and development activities. In Africa, several companies (including Microsoft of USA, Siemens of Germany, Vivendi of France, Masreya of Egypt, the MIH group of South Africa) have collaborated to develop wireless, satellite-based information and communication systems in a number of countries. Other companies challenge college students to solve problems faced by the industry, offering rewards for the best solutions. Students are intellectually challenged with real-life problems and industry gains a range of often-innovative solutions. Again, such efforts should be expanded through the participation of the private and nongovernmental sectors.

The practice of some national governments in offering tax benefits to companies that establish in-house research and development units, and hire scientific talent within their borders, is also worthy of attention. The reverse situation can also pay dividends for the development of local science and technology – namely applying a tax or levy on specific industry products and using the funds collected to support research and development in that sector. Thus, the Malaysian government levies rubber, palm oil and timber production to fund the Rubber Research Institute, the Palm Oil Research Institute and the Forestry Research Institute. Likewise, the Sri Lankan government collects a levy from tea sales to fund tea research and marketing initiatives.

13. Government Investment in Science and Technology

***Action Point:** Persuade governments to invest adequately in science, education and health, with the science sector receiving at least 1 percent of the GDP and the education sector at least 6 percent of the GDP.*

Although the private sector has been helpful in some national and regional efforts, as described above, governments in most developing countries must take the major, if not the entire, responsibility to support science and education. This is because there is little industrial support available in these countries and even where there are private research initiatives, these tend to be undertaken in-house and targeted toward their own agendas, thus providing little or no support to extra-institutional activities.

Governments must be the responsible instruments of change and development within each nation. Science is by far the greatest force for change in the modern world, and education is the only means to ensure the production, communication and sharing of scientific knowledge. To this end, governments should take full responsibility in the fields of education, health and the welfare of their citizens. Academies of science and other professional bodies must persuade Third World governments to invest at least 1 percent of their gross domestic product (GDP) on science and technology and at least 6 percent of their GDP on education (with more than 2 percent earmarked for higher education).

Trans-national agencies such as the regional development banks, the World Bank, the Organization for Economic Cooperation and Development (OECD) and UNESCO should create platforms for science leaders to interact face-to-face with ministers of finance, industrialists and business leaders, in order to sensitize and convince them of the utility and value of such commitments to the cause of scientific capacity building and consequent improvement in the quality of living. At such meetings, the scientific community should provide examples of successful experiences where investments in education and in science and technology have helped solve real-life problems. Such examples should highlight findings such as the fact that there is a direct link between increased literacy rates of women at the secondary school level and a

***Funds for Brazilian science.** In 2001, the Brazilian government introduced a scheme whereby funding for scientific research is raised by so-called 'sectoral funds'. Under the scheme, taxes are levied on companies working in various sectors, including biotechnology, energy and nanotechnology, and subsequently used to fund research in that area. In this way, more than US$400 million is raised each year. Although there have been teething problems in the administration and disbursement of the collected funds, the system provides a way of injecting much-needed money into research programmes while ensuring that such programmes are directly relevant to the country's social and economic needs.*

reduction in family size; the incidence of many infective diseases can be reduced by simply providing clean water; and the introduction of selective breeding and biotechnological methods have dramatically improved crop yields and food security.

***China's spending on science**. After decades of economic stagnation, China now has one of the fastest growing economies in the world. Among the political changes that have driven this transformation is an increased investment in science and technology. Indeed, between 1990 and 2002, the proportion of China's GDP spent on research and development doubled from 0.6 to 1.2 percent. These figures are reflected in the budget of China's National Natural Science Foundation, the country's major grant-awarding body, which increased from US$10 million in 1986 to some US$300 million today – a thirty-fold increase. Research funds are awarded to Chinese scientists in an open, competitive process, especially in such key development areas as bioinformatics, nanotechnology, the regional response to global climate change and the modernization of traditional Chinese medicine.*

Epilogue

There is no single strategy for promoting sustainable economic development in the South. Many systems and schemes have been tried – some with more success than others. However, TWAS asserts that, for successful development to take place, countries must focus their efforts on building a sound base in science and technology, including science education.

For developing countries to fully exploit all that science can offer, capacity must be built and sustained, both at the individual and institutional level. The real challenge is to maintain a critical mass and an optimal capacity of highly qualified and innovative scientists and technologists in each country. If implemented across the board as a 'collective whole', the 13 inter-linked action points outlined in this document will help developing countries begin to realize their full potential and set them on the road to closing the gap between themselves and the world's developed nations in the near future. Indeed, examples are given of successful initiatives in many of the areas addressed that can be used as viable foundation stones for the expansion of such programmes to other countries in the South.

As Abdus Salam, the Pakistan-born Nobel laureate and TWAS's founding father, noted more than two decades ago: “Scientific knowledge is the common heritage of humankind.”

Only this treasure of humankind can provide the means to conquer inequality and to bring about an acceptable standard of life for the majority of the peoples of the world. By working together, governments, scientific organizations, other nongovernmental organizations and the private sector can ensure that the benefits of science are made available to all.