Series on Science for Sustainable Development No. 5

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Science Education and Capacity Building for Sustainable Development

ICSU Series on Science for Sustainable Development

The ICSU Series on Science for Sustainable Development is produced by the International Council for Science in connection with preparations for the 2002 World Summit on Sustainable Development (WSSD). The aim of WSSD is to bring together governments, United Nations agencies and other key stakeholders, including representatives of civil society and the Scientific and Technological Community, to build upon the 1992 United Nations Conference on Environment and Development (UNCED) and to enhance efforts toward the future of sustainable development. The Series includes a set of inter-disciplinary reports focusing on major issues that are relevant to science for sustainable development. The Series is meant to serve as a link between the scientific community and decision-makers, but the reports should also be useful to all others interested in the contribution of science to sustainable development. The Series highlights the fundamental role science has played and will play in finding solutions to the challenges of sustainable development. It examines experiences since UNCED and looks towards the future. It provides up-to-date knowledge, examines lessons learned, successes achieved, and difficulties encountered; while also outlining future research agendas and actions to enhance problem solving and good practices in sustainable development. The Series was made possible due to a generous grant provided by the David and Lucile Packard Foundation.

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Science Education and Capacity Building for Sustainable Development

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Preface

While it is necessary to build and enhance strong scientific and technological capacity in all regions of the world, this need is particularly pressing in developing countries. The Organization for Economic Co-operation and Development (OECD) countries spend annually more on research and development (R&D) than the economic output of the world's 61 least developed countries. Developed countries employ twelve times the per capita number of scientists and engineers in R&D in comparaison to developing countries, where there is woefully weak institutional S&T capacity. Ten years after Rio, this challenge remains a major obstacle to sustainable development. Developing countries must address this problem and significantly increase investment in higher education and S&T capacity building.

The responsibility for building and maintaining this capacity lies squarely on the shoulders of national governments but requires significantly enhanced collaboration and partnerships with the private sector, the global development assistance community and the S&T community. Developed countries must accept their responsibility for much improved knowledge and technology sharing. Bilateral donors and other funding bodies should substantially increase the funds they allocate to S&T for sustainable development, specially in the area of science education and capacity building.

Throughout the preparation for the World Summit on Sustainable Development (WSSD), the S&T community, governments and other stakeholders have stressed the need for making science education, and capacity building in science and technology priority areas in the further implementation of Agenda 21 and in moving towards sustainable development.

During the WSSD preparatory process representatives of the international scientific and technological community, of relevant intergovernmental organizations, governments and representatives of other major groups have agreed to explore together the launching of an international S&T capacity building initiative as a concrete follow up to the WSSD.

In order to identify more clearly the necessary action to be taken towards enhancing science education and capacity building, the International Council for Science (ICSU) has convened a small working group to draw up a document outlining the case for increasing efforts in science education and capacity building, and proposing some of the steps that are necessary, if such a capacity building is to be achieved.

This report represents the results of the ICSU working group and its recommendations. We are very grateful for the dedicated work of the members of the group. It is my hope that the Report will also be used as an inspiration for the way ahead in building S&T capacities for sustainable development.

The report will be one important input to the ICSU Strategic Area Assessment on Capacity Building which is being launched by the ICSU Scientific Commitee on Planning and Reviev.

Professor THOMAS ROSSWALL

Executive Director
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Executive Summary

One of the biggest tasks facing those addressing the challenge of sustainable development, both in developed and developing countries, is the need to generate the capacity to apply science and technology to this goal.

Aware of this requirement, the International Council for Science (ICSU) convened a small working group to draw up a document outlining the case for increased efforts in capacity building in science and technology, and proposing some of the steps that are necessary if such capacity-building is to be achieved. The group was made up of individuals representing a range of institutions and points of view on the role of science and technology capacity building in promoting sustainable development. The issues that it considered included:

- the general case for capacity building for science and technology, particularly in the context of the implementation of Agenda 21;
- the importance of primary and secondary education as an essential element of building science and technology capacity;
- the need for integrated approaches to issues relevant to sustainable development at the tertiary level;
- the importance of building the capacity of research communities to address topics related to sustainable development in an effective manner;
- the key role of international cooperation, both North-South and South-South, together with the need to address the impact of the so-called 'brain drain' (or 'brain gain') on science capacity building; and
- the central role of capacity building in science and technology communication as a contribution towards achieving the goals of sustainable development.

In addition to specific actions proposed under each of these issues, several overarching themes that affect the implementation of such proposals were recognized. These included:

- the need to consider issues more systemically, and not in isolation;
- the need to recognise that sustainable development topics in general are more likely to be interdisciplinary or multidisciplinary in their focus, to incorporate issues related to social impact, to include local knowledge, and to draw upon work with communities.
- the need to consider the role of multiple actors, and the importance of critical partnerships with communities, governments and other interested organizations; and
- the need to place particular emphasis on issues related to girls and women.

During the discussions, the group agreed on a set of general principles intended to underpin its specific recommendations for ways of supporting capacity building in science and technology for sustainable development.

These general principles included that fact that the responsibilities of the scientific community need to extend beyond the internal concerns of the community to include:

- research that is oriented specifically to problems related to sustainable development;
- science education and training at all levels, particularly in those aspects focusing on sustainable development; and
- communication about science and technology that relates to sustainable development.

Drawing on the general principles outlined above, the working group made a variety of recommendations in each of the areas that it considered. Some of these address practical ways that the scientific and technical communities might better support capacity building for sustainable development. Others addressed the challenges in providing such support, both from within and outside of these communities.

Main Recommendations

Recommendations for further action are included in each individual section of the report. Those listed below are considered to be the top priorities for implementation during the follow-up to the World Summit on Sustainable Development.

PRIMARY AND SECONDARY EDUCATION

- The teaching of science through inquiry-based, hands on approaches at primary and secondary levels needs to be incorporated as a fundamental component of basic education in both developing and developed countries. Its essential role must be recognized, as it prepares children to live and work in a world increasingly defined by science and technology, equipping them for personal decision-making and for their roles as citizens. Policies that affect finances, curricula, teacher preparation, materials development and assessment to support this critical goal must be established.

- Topics important for sustainable development, such as the relationship of science and technology to health, energy, food production and the environment, should be included while providing basic conceptual frameworks for lifelong learning. Scientists should assist curriculum developers in identifying relevant topics, incorporating science themes into the coverage of such topics and creating appropriate materials for teaching and learning.

- It is especially important to ensure that girls and young women (as well as boys and young men) receive high quality education, given their current under-participation in basic education and in scientific and technical courses at all levels, in addition to their roles within the family, community, society and economy.

- The scientific community must build meaningful partnerships with governments and schools to support quality science and technology education in primary and secondary education. The roles that scientists and engineers can play include: serving as advocates to governments and to donor agencies to support quality approaches to learning and teaching science, mathematics and technology; and working with teachers and educational administrators to support the development, implementation, scaling-up and sustaining of quality, hands-on science instruction in schools.

TERTIARY EDUCATION AND RESEARCH

- For universities to take the lead in the changes required for science to respond to the challenges of sustainable development, they must revise their curricula, the organization and assessment of research, and their working links with different sectors of society.

- This is especially true in those areas where sectors such as non-governmental organizations, local communities, small enterprises, and so on, are to play a role as partners in sustainable development efforts.

- Universities and higher education institutions need adequate and stable funding to maintain their capacity to engender innovation and provide quality education. Cuts in the budgets of public universities are therefore a threat to capacity building for sustainable development, and should be a matter of serious consideration by national governments.

- Group work among students and multidisciplinary training should be promoted. Students pursuing studies in any single discipline should be required to take at least a course in another discipline or a multidisciplinary subject of relevance to sustainable development.

- Research of high quality and relevance related to sustainable development, especially that carried out in developing countries, should be recognized in specific ways, for instance through international awards. The nomination of developing country scientists to international committees should be encouraged.

International Cooperation

- Support for international science programmes to incorporate capacity building in the South into their core activities.

- Increased support for undergraduate, graduate and postgraduate South-South fellowship programmes devoted to quality training in science and technology. These programmes should utilize the best research and training centres in the South to attract and train the developing world's most talented students.

- Continued development of South-South science-based institutional networks to share innovative experiences and address critical environmental, public health, and social problems. Such networks should pursue joint problem-solving research activities and devote the time and resources necessary to describe and discuss their experiences with others both within and beyond the scientific community.

- Support for proposals to build international scientific research centres in the South that focus on such critical issues as tropical diseases, renewable energies, biotechnology, and information and communication technologies. These efforts should explore both the possibility of upgrading competent national and regional centres or creating entirely new centres where they do not exist.

- Continued support for the creation and strengthening of international and regional networks of science academies taking place, for example, through the InterAcademy Panel on International Issues (IAP), the Association of Academy of Sciences in Asia (AASA), the All European Academies (ALLEA) and the Caribbean Scientific Union.

- Mobilization of expatriate third world scientists living and working in the North to examine critical problems in developing countries together with their colleagues in the South, and to assist in building the capacity and excellence of scientific institutions in the developing world. Such efforts could prove instrumental in turning the brain drain into a brain gain.

Science communication for sustainable development

- Governments and aid agencies should be encouraged to support, with the backing of scientific and technological communities, national or regional workshops and training courses intended to develop the professional skills of those engaged in different aspects of the communication of science.

- An introduction to the goals and concerns of sustainable development – and of the potential impact of science and technology, both positive and negative, on these goals – should be included in both the formal and informal training received by all those professionally engaged in the communication of science.

- Associations and networks of individuals from each of the four professional groups of researchers, science and technical journalists, science information officers, and museum/science centre curators, should be organized at both national and regional levels, allowing them to communicate and interact both within their respective professions, and between/among professions.

- Encouragement should be given to the publication of popular books and magazines, as well as theatrical presentations, radio and television programmes, and other forms of mass communication, intended to help the public become sufficiently informed about the nature and impact of key scientific and technological developments to participate effectively in debates about them.

Introduction

For science and technology to be able successfully to achieve the goals of sustainable development, countries need the capacity to engage creatively in science education, scientific research, the development of new technologies, and their application to economic, social and human needs.

The need for capacity building in each of these spheres of activity exists in developing and developed countries alike. The former frequently lack either the resources or infrastructure necessary to build a basic capacity in science or technology; there are schools in Africa that have a single, carefully-kept beaker to demonstrate to children how chemistry is done by those with the privilege of having easy access to basic laboratory equipment. But developed countries have needs, too. For example, there is a need to encourage a more multidisciplinary and interdisciplinary approach to problem-solving, one that incorporates social and environmental goals into research agendas, rather than letting such agenda be determined either by scientific curiosity alone (important though such curiosity remains), or by a commitment to narrow concepts of economic growth and profitable industrial innovation.

This report has been prepared as a step towards enhancing science and technology capacity in both developed and developing countries, within a broader commitment to sustainable development. We have started by setting out the nature of the issue. We outline the ways in which building up a robust capacity in science and technology is an essential requisite for any nation determined to address the challenge of sustainable development. We also outline some of the new ways of doing science (for example by allowing greater stakeholder participation in both determining research priorities and engaging in the research itself, or greater interdisciplinary collaboration) that are necessary if this goal is to be achieved.

The following sections of this report address the need for capacity building in three separate areas: education (at the primary, secondary and tertiary levels); research (including, for example, the need for stable research budgets, for truly interdisciplinary work, and for greater collaboration, particularly among countries in the developing world); and in the communication of science (which plays a critical role in ensuring that the political decisions needed to achieve sustainable development are based on informed debate at all levels of society).

Each section contains recommendations on how needs might be met. These are addressed at two separate audiences. The first are those in society at large who are in a position to make the necessary choices, as well as the decisions that are needed to implement them. These range from political leaders and international funding agencies, to the local groups whose 'empowerment' is a key element in any successful strategy to promote or achieve sustainable development. The second audience is the scientific community itself. We hope that our comments and conclusions will provide an opportunity and incentive for self-reflection that will lead scientists to consider how they need to rethink some of their traditional practices on the way that science is taught in order to contribute in a positive way to the achievement of sustainable development.

We fully realise that the successful implementation of capacity-building strategies for science and technology requires other factors that lie outside the remit of this report. In particular, they can only take place in a secure and stable social environment, free of the disruptions of war and social conflict, and immune from the pressures of political corruption. Overall, however, our hope is that the conclusions and recommendations in this report will help to focus the minds of decision-makers, scientists and the public alike on some of the key issues that need to be addressed if the world's capacity to develop the initiatives necessary for sustainable development is to be successfully enhanced.

The Need for Science Capacity Building

The term capacity building is used in a variety of contexts and with different connotations, which are most often not made explicit. In particular, it is frequently used with reference to just one aspect, namely the education and training of scholars.

There is no doubt that education and training are at the heart of development efforts. But it is also essential to expand beyond this notion to include other aspects critical to creation of an infrastructure for scientific and technological capacity building.

In 1991, the concept of capacity building was appropriately defined by the United Nations Development Programme in this broader sense to encompass:

- the creation of an enabling environment with appropriate policy and legal frameworks;
- institutional development, including community participation
- human resources development and strengthening of managerial systems.
- capacity building as a long-term, continuing process, in which all stakeholders participate (ministries, local authorities, non-governmental organisations, producer and user groups, professional associations, academies and others).

This is the approach that is used to capacity building within this report. It is important to stress that:

- Science capacity-building encompasses a multiplicity of resources, actors and of organisational and institutional components (of which the education and training of scientists is only one central and necessary component) interacting in a long-term systemic process.
- All sectors of society and stakeholders should play a role and participate in the process.
- The issues listed above are required not only to develop but also to sustain and fully utilize science capacities.

Problem solving and capacity building

The "problem solving" approach vs. the "capacity building" approach has long divided donor countries. During the course of the last decade, however, an increasing number of donors and recipients have recognized the need to replace research and policies defined by supply with almost exclusively demand-oriented policies. Such moves are consistent with evolving notions of development, based on a commitment to capacity building, that were pioneered by institutions established in the 1970s in countries such as Canada and Sweden. As a result of this shift, a consensus seems to be emerging around a concept reconciling the two approaches: namely, "problem solving through capacity building".

Science and technology activities have been acknowledged as important components of economic development. While recognizing education and training as important inputs into development, other aspects have been argued to include a certain level of investment in research and higher education in order for scientific development to take place.

Starting with individual scientists and their capacity and dedication to do the research, we can link to three organisational needs: (I) national co-ordinating bodies for facilitating the working environment, collaboration/networking, setting priorities and allocating resources; (II) higher education systems for the production high quality scientists; and (III) scientific and managerial capacity to design research programmes aiming at achieving priority goals based on peer review and quality control.

We can also move from individual scientists to three other types of needs: (I) the resources and physical infrastructure required to carry out the programmes, such as buildings, laboratories, research stations, research vehicles and supplies; (II) the need for integration into regional and international science; and (III) the need for the capacity to link research to development in a larger policy context.

In addition, it should be remembered that conditions external to the scientific enterprise are clearly necessary to support capacity building for sustainable development, including some level of economic, social and political stability. Similarly, peace, equity and justice are pre-conditions for sustainable development to take place.

Partners In Sustainable Development

Broad participation and inclusiveness are seen to be key to the success of sustainable development. All sectors of society have a role to play in the process, each one in its own capacity.

Popular participation and environmental management at the local scale have proved to be of great benefit in sustainable development initiatives. Hence, the development of innovative capacities at the local level is a priority – mobilizing, in particular, local resources and local knowledge to solve local problems that, in turn, will have beneficial global impacts.

All stakeholders, including local governments, non-governmental organisations, the industrial sector, learned societies, schools and community groups, need to participate in the capacity building efforts. Human resource development should focus on a series of actions directed at helping participants in the development process to increase their knowledge, skills and understandings, and to develop the attitudes needed to bring about the desired developmental change.

The need for broad participation is not just a matter of equity or democracy; it has to do with bringing together a wealth of knowledge, values, approaches and experiences that can and must mutually enrich each other. In particular, the multiplicity of forms and systems of knowledge about nature and the human being that have developed over centuries in different parts of the world, prove today to be an invaluable asset in meeting the challenges of sustainable development. In fact, a considerable number of documented experiences indicate that traditional and scientific knowledge play a complementary role and that they need to cooperate more closely than they have so far, to advance the much needed understanding of nature and its interaction with human beings.

More efforts must therefore be undertaken to build a fair relationship between scientific and traditional knowledge, to strengthen the capacity of communities to revitalise and manage their own knowledge base, and to promote the integration of local knowledge, values, traditions and practices, in sustainable development projects.

Coping with the Brain Drain

There are differing views on the effects of international scientific migration, which can be traced to its intrinsic character as a polymorphic, recurrent phenomenon whose costs and benefits have never been successfully evaluated. The tendency to assign countries the status of “winner” or “loser” in migration patterns is of dubious usefulness in an era of changing economic paradigms and increased interconnection of scientists via electronic communication networks. Nevertheless, those developing countries with neither improving economies nor easy and inexpensive network connections often still find themselves at a disadvantage in the global flow of scientific talent.

Linking the migration of well-educated people to the development of poor countries is not a new idea. Until the late 1960s, it was seen as the best way of transferring technology to the Developing World. But the belief did not last long, since it was demonstrated in the 1970s that the great majority of developing countries’ students, who were trained in the Noth, did not return home. However, not all countries abandoned the original idea, and some of them still consider that their highly qualified expatriates could constitute a stock of well trained people abroad to be drawn on whenever needed. Different policies for recovery of their high-qualified nationals abroad were thus implemented during the 1980s and 1990s.

South East Asian countries like South Korea, Taiwan and Singapore provided conclusive proof that highly-skilled emigrants can largely contribute to the development of their countries of origin and that the circulation of people and knowledge between source countries and host countries is a very powerful development tool. However, it can be drawn from their experience that brain drain cannot be changed into brain gain without a strong political will from source countries aiming at developing jointly their home-based scientific, industrial and economic potential. In other words, it is impossible to enter a virtuous circle (that returning knowledge and people improve the scientific and economic level of their home country situation which in its turn, stimulates further returns and so on) if a long lasting development policy is not at work at home.

Other countries have, during the last decade, been mostly relying on the reconnection, by way of networking, of their expatriates to serve their national interests. The idea is to make an inventory of the highly qualified nationals abroad, to mobilize and organize them, to reconnect them with the scientific, economic and industrial community at home in order to capitalize on their work and networks, and introduce them on the local scene. This is known as the "Diaspora option". These "reconnection programs" seem at first sight to be less demanding from home countries than the traditional return policies as implemented in South East Asia, but very little is known as yet of their effectiveness. Nevertheless their limits have been documented. One of the preconditions for this "reconnection" of well-educated expatriates with their country of origin to be productive in terms of development is the existence of a dense and well-developed national community of scientists and technologists for areas of interface to be defined.

Without a minimum of correspondence of interest between the highly educated community present on national territory and that of the expatriates, it would be difficult to effect exchanges and collaborative projects. Another weakness of the system lies in the fact that it is the result of a political will, which means that its survival depends on just that. This explains perhaps why many projects started during the past ten years are no longer operating. Consequently, since the whole of the preconditions necessary for building up and maintaining the networks (in other words long-term political will, sustained administrative capacity and the existence of a substantial endogenous scientific community) are far from being fulfilled by a lot of developing countries, notably in Africa, the "Diaspora option" cannot be considered as an alternative to other policies and programmes, but more as a measure among others to create and strengthen capacity building.

In those countries where the minimal socio-economic or professional conditions needed to initiate any sort of return are not accessible and where brain drain cannot be compensated by any form of circulation, North-South cooperation and national programmes for capacity building are very important. This is particularly relevant in the current context of globalisation where industrialised countries, facing today a broad shortage of highly qualified scientists and technologists are initiating very selective immigration regulations and trying by all means to attract highly educated people from all over the world.

At the same time, as mobility has become more and more perceived as an added value in the labour market, universities have been assigned a primary role in the current international economic competition. As a of consequence, universities in the North threatened by the decrease of their domestic college-age population, are more and more engaged in aggressive recruitment campaigns in order to increase the number of their foreign students (taken today as an indicator of their international stature and their powers of attraction on the extremely lucrative international market for higher education).

Another shift connected with globalisation relates to the way science is practised. Scientists are increasingly leaving the academic sphere to enter the field of business, where scientific knoledge is often considered as a commercial weapon that should not be shared. This ongoing trend may seriously jeopardize the emergence and the stability of national scientific and technological communities in the South, exacerbate the mobility of scientists and contribute to increased brain drain.

Emerging science and technology communities are particularly vulnerable. The last decade's history shows how even very strong science and technology systems can be affected by economic collapses. There are today concerns about the future of science in Argentina. Another example is South Korea, where despite the reverse flow of migration of educated people from the United States in the 1980s and 1990s, authorities are now worrying about a growing trend of re-emigration to the US of those science and technology qualified workers who settled back home in the last decades.

Without either a very strong political will or active cooperation programmes, brain drain can hardly turn into brain gain. While highly qualified migrants can doubtless contribute to the S&T capacity building of their country of origin, their contributions have to be encouraged and optimised through cooperative agreements based on a win-win principle that mobilizes energies in both industrialised and developing countries.

If nothing is done for the countries where no circulation is possible, since the conditions are unsuitable for either collaborative schemes or for the return of skilled people, they are in danger of finding themselves quickly in an impasse. Unfortunately, in a context of public budget cuts, it is unlikely that mobilization of their resources alone would be sufficient to providing lasting solutions. For these countries, it is imperative to keep up and renew international efforts of solidarity in order to strengthen their research capacities and to enable as many as possible of their researchers to exercise their profession in more favourable conditions so that they do not give up and go abroad permanently.

Box 1: IFS and Science Capacity Building in the Developing World

The *International Foundation for Science* (IFS) has supported many more than 3,000 developing country scientists over the recent decades in sciences related to the management, conservation, and sustainable use of natural resource.

As part of the Monitoring and Evaluation System for Impact Assessment (MESIA) being established at IFS, a tracer study of IFS grantees has been conducted in a selected number of countries including Cameroon Mexico, Morocco and Tanzania.

Paradoxically, very few cases of true brain drain were found in the surveyed population. Out of some 400 scientists surveyed and some 30 years after the first grant had been approved, six only had emigrated permanently to the United States and Europe.

Most of the remaining scientists were still active in their respective countries except for Tanzania were some 10 per cent were found to contribute to a regional circulation of scientists in Southern Africa. This shows that support well targeted to young scientists at the beginning of their research careers can be instrumental in retaining them in their national scientific communities.

Gaillard A-M and J. Gaillard. 1998. The International Circulation of Scientists and Technologists. A Win-Lose or Win-Win Situation? Science Communication, Vol.20 No.1, 106-115.

Primary and Secondary Education

Primary and secondary education in science and mathematics is an essential component of capacity building, providing the fundamental background needed to produce the next generation of scientists and engineers as well as the foundation for lifelong learning about science and technology. Teaching science to children is essential to providing them with a basic understanding of the world, a critical tool increasingly needed to manage in daily life. In addition, science provides tools needed to distinguish fact from fiction, to value evidence, and to respect and value the process of searching for truth.

Whether in the development of political leaders, scientists, engineers, health care providers, natural resources managers, or informed citizens, education that begins at the primary and secondary levels is central to this process. And as the knowledge necessary to realize sustainable development has increasingly encompassed scientific and quantitative concepts, as well as technology, education in these fields has become essential in developing and developed countries alike.

Science as basic education

The World Conference on Education for All was held in 1990 in Jomtien, Thailand. At that time, the nations of the world met to identify universal goals for education and literacy. Among the goals articulated was universal access to primary education for every child. More than 180 countries participated in the follow on effort of taking stock to determine what had been accomplished between Jomtien in 1990 and the April 2000 World Education Forum held in Dakar, Senegal.

The findings can be summarized as follows:

- There are more children attending school than at anytime in history. Yet there are still 113 million children out of school, 97 percent of them in less developed regions of the world and 60 percent of them girls.
- Some regions of the world have made great progress and are on course to achieve universal access to education, especially Latin America, the Caribbean and East Asia.
- Unfortunately in Sub-Saharan Africa there has been an increase in the number of children not in school. There has also been loss of ground in early childhood care and education in some of the countries of the former Soviet Union.

In the Jomtien Declaration there was the broadest possible interpretation of basic education that included formal schooling as well as informal and non-formal learning that takes place in the home, local community and elsewhere. There were also country-by-country definitions of what was meant by basic education. This included level as well as content of education. Virtually all countries included the primary years within their definition. Examples cited in the World Education Forum Global Synthesis document included: Brazil, which in 1996 defined the entire system from day care to the end of secondary school as basic; Nigeria, which referred to early childhood and pre-primary, primary and the first three years of secondary school as basic; and China, which is shifting from primary to nine year compulsory school preceded by early childhood care as basic.

The document defined the topics covered in "basic" as "the competencies, knowledge, attitudes, values and motivations that are deemed necessary in order for people to become fully literate and to have developed the educational foundations for a lifelong learning journey". The core curriculum inferred from this was seen as including "numeracy, social and scientific knowledge, physical and health education and the arts and crafts." Although science was seen as part of the core of subjects that collectively formed basic education it is not clear how much science is really taught at primary and secondary levels. It is also not clear whether science is taught in ways known to be effective and consistent with how children come to understand the world and how it works.

An emphasis on authentic, hands on, inquiry- based approaches has emerged as the preferred pedagogical approach to learning science. Building on children's reality, interests and ways of learning, and using local contexts and local examples provide opportunities to teach fundamental ideas in ways appropriate to local needs for developing a knowledge base to achieve local development. In addition the rapid expansion of technology supports the need for students to become more technologically literate as well as supporting the use of technology, where possible, to support learning.

The extent to which the preferred science learning style will be incorporated into instruction is directly related to the capability and experience of teachers at the primary and secondary levels to employ hands on science strategies. The ability of teachers to employ such strategies will depend on the nature of their own education as well as the extent to which relevant professional education experiences have provided an opportunity for them to learn and teach using hands on, authentic approaches.

Educating for Sustainable Development

Major themes related to sustainable development include health, environment, energy and agriculture. A science education curriculum is often developed around these themes. For example, one specific project undertaken in Nigeria, Early Learning Science Series for Africa, supports literacy goals as well as hands on science, and involves culturally important activities such as plays, songs and poems. The themes covered in the series include malaria and HIV/AIDS. In Sri Lanka, the environment is the basis for teaching science. The science curriculum for Grades 3 to 6 in Indonesia include themes such as: life and living; materials; energy and change; Earth and beyond; and technology. Clearly within these themes are opportunities to explore issues critical to sustainable development.

In addition to specific content knowledge there are other learning objectives for primary education expressed in the examples provided above:

- A focus on observing, exploring, appreciating and protecting the environment;
- Developing functional knowledge of basic science concepts and principles as well as basic science process skills;
- Developing basic understanding of natural phenomena;
- Developing scientific attitudes (habits of mind) including curiosity, objectivity, critical reflection;
- Being able to apply knowledge and skills gained to solve everyday problems;
- Developing self-confidence and self-reliance through problem solving.

There is evidence to suggest that including such relevant, practical themes within science content and moving to more hands on approaches increases interest in science courses, including among girls.

The teaching of science at secondary levels tends to move away from integrated themes toward specific disciplinary foci such as chemistry and physics. Opportunities must be found to incorporate integrative projects with themes important to sustainable development within the specific study of the disciplines. As concerns increase about declining enrolments in science and engineering programmes, attention must be given to how the content of courses and modes of teaching can be changed to attract students. While primary science topics can be taught without labs and extensive equipment, secondary science requires at least a minimum amount of infrastructure.

One example for lowering the cost of secondary science was provided at the workshop sponsored by the ICSU Committee on Capacity Building in Science, held prior to the World Conference on Science in Budapest in 1999. Here a project known as Radnast was presented involving a portable chemistry "lab"developed for use in South Africa. Using small amounts of chemicals it is possible to demonstrate fundamental principles in a "hand-held lab". Such micro-scale chemistry examples hold great promise for providing authentic or meaningful experiences with lower costs and easier disposal of spent materials.

In addition to challenges of appropriate curricular content needed to support ideas of sustainability and inadequate infrastructure for instruction, perhaps the greatest challenge to providing authentic forms of learning and teaching in science is in the capacity of teachers. Most have not been educated in ways that reinforce hands on inquiry-based approaches to instruction or incorporation of topics from local contexts that may require an interdisciplinary focus. The education, training and continuing professional development of teachers must include such approaches as well as ongoing content support from the scientific and engineering communities.

The role of scientists, mathematicians and engineers

The Declaration from the World Conference on Science, held in Budapest in the summer of 1999, reinforces the idea that "science education is essential for human development, for creating endogenous scientific capacity and for having active and informed citizens". Scientists, mathematicians and engineers are essential to the process of developing the capacity of nations to provide quality education in science at primary and secondary levels. This involvement may take many forms, but at least includes the direct science and mathematics content preparation of teachers.

The teaching of the subject areas at tertiary levels as well as the form of instruction is the purview of the scientific and mathematics communities. Values about the nature of science and mathematics and their role in capacity building for sustainable development should be reinforced by members of these communities. Scientists, mathematicians and engineers represent the basic scientific and technological capacity of a country. They must be involved in working across a variety of formal and informal institutions, in higher education, and with governments in the expansion of that capacity within their countries.

In addition to direct content instruction in the preparation of teachers, scientists have played other roles in capacity building. These include:

- Advocacy to government for quality science curriculum and instruction;
- Involvement in the continuing education of teachers;
- Development of curriculum and other resource materials;
- Ongoing content support of teachers in the field; and
- Dissemination of best practice.

Many academic science and technology centres provide valuable support to primary and secondary education. In addition to their role as informal learning environments, many provide professional development to teachers and complement school science through visits and production of curriculum resources.

Recommendations

- Science education should be included as a fundamental component of basic education. National governments should provide financial support for development of curriculum, materials, teacher preparation, and continuing professional development as well as assessment that supports this goal.

- Quality hands-on science education should be provided to girls and young women (as well as boys and young men) at primary and secondary levels, given current female under participation in terms of general education, science and mathematics courses, jobs and careers. It is also critical to provide access to science because of women's roles within the family, the community, society and the economy.

- Scientists should be advocates for teachers, and educate them to teach science through inquiry-based, hands-on approaches. They should help in the development of science programs that incorporate topics important in sustainable development, such as health, energy, food production, and the environment, while providing basic conceptual frameworks for the science and technology essential for lifelong learning.

- Problem-based approaches that are more interdisciplinary as well as fundamental ideas of the disciplines should be included in teaching science, especially where these approaches address local issues related to sustainability.

- Information should be made widely available on resources for science, mathematics, and technology education, including such elements as models effective in attracting girls as well as boys and low cost models for lab- and field-based science instruction at the secondary level.

- Internet-based resources, paired with extension workers and scientist volunteers, have the potential for wide distribution and widespread impact. Scientists and engineers must have increased interaction with teachers to provide ongoing support for quality, hands-on science instruction in schools.

- Scientists and engineers must become advocates to local and national governments for quality approaches to learning and teaching science, mathematics, and technology. Partnerships among the scientific and technological communities, governments, and educators are needed to develop, implement, scale-up, and sustain quality science, mathematics, and technology education.

- Science and technology centres should be supported in partnerships to provide quality professional development for teachers and science curriculum resources to schools.

Box 2: 1st International Conference on Primary School Science and Mathematics

Education

The 1st International Conference on Primary School Science and Mathematics Education was held in Beijing, PRC in November 2000. The meeting provided an opportunity to share experiences and outcomes from efforts around the world to support uses of hands-on approaches to science instruction.

The conference also played a catalytic and supportive role for science education reform within China. Policymakers at the highest level, practitioners and higher education faculty were able to share ideas and learn about efforts undertaken by scientists in other countries. These initiative included work by scientists to establish professional development programs for primary school teachers of poor and minority children (Chicago and France) and advocacy to governments in support of reform (France).

"La Main a la p te", an inquiry-based, hands-on program developed in France provided examples for ongoing online support of teachers through efforts of the French Academy of Science. The conference itself provided an opportunity for regional networking as well as for dissemination of promising practices.

An Asian Pacific regional conference held in Malaysia in October 2001 grew out of the recommendations from the Beijing conference. It provided an opportunity to explore regional collaborations as well as for the host Malaysian Academy of Science to support science education reform within the country. Networking with the French Academy of Science as well as with the ICSU Committee on Capacity Building and area scientists provided models to government decision makers to consider in promoting hands-on science in the country.

The occasion of the Beijing conference supported developed and developing science education reform efforts in other countries of the region such as Thailand, Indonesia and Sri Lanka.

In addition, there has been a ground swell of involvement by a number of the science academies across the globe (Brazil, Chile, France, India, Malaysia, Mexico, Senegal, the United States, and others) in the issues of primary science education, a topic generally not considered by groups at this level. Working through ICSU and the InterAcademy Panel, links are being forged between education and science communities at the highest levels, a website is being developed to share experiences and resources, and leadership is being exercised to move forward to make this a worldwide agenda.

Universities and Research Institutions

"The ultimate goal of education for sustainable development is to impart the knowledge, values, attitudes and skills needed to empower people to bring about the changes required to achieve sustainability. Quality education for sustainable development needs to be based on state of the art knowledge and to continually review and update curricula and teaching materials accordingly."

This quotation comes from The L neburg Declaration on Higher Education for Sustainable Development, a document issued in October 1999 by an important number of international partners. The declaration identifies a variety of ways in which the higher education institutions should work to address the critical challenges of sustainable development, and calls on governments to ensure that the WSSD includes education in general, and higher education in particular, in the future programme of work.

Universities and other institutions of higher education are in fact a necessary component - the crucial node - in a healthy system of science and technology for sustainable development. A weak university system undermines the ability of a country not only to develop, but also to retain, young scientific talent.

Underfunded universities often degenerate into profit-seeking organizations with poor track records of engendering innovation and providing quality education. The reduction of budgets of public universities - which is taking place on a widespread scale in various parts of the world - is therefore a major threat to capacity building for sustainable development, and should be a matter of serious concern.

Another problem is that fact that at the undergraduate level, students receive a mono-disciplinary training of high specialization and oriented to specific topics and their efforts are geared towards individual performance rather than collective work. The landscape of scientific training can be characterized as one of deep tunnels instead of wide horizons. Group work among students should be favoured, and students pursuing studies in any single discipline should be made to take at least a course in another discipline or a multidisciplinary subject of relevance to sustainable development.

The epistemological, methodological, organizational and institutional changes that need to take place for science to respond to the challenges of sustainable development, are a matter of serious consideration by the higher education system, where most public research is carried out. For universities to take the lead in these changes, they must transform themselves in various ways, notably by thoroughly revising their curricula, the organization of research, and their working links with different sectors of society. This is especially true in those areas where sectors such as non-governmental organisations, local communities, small enterprises, and so on, are to play a role as partners in sustainable development efforts.

Promoting a sustainable development-oriented science

Promoting a sustainable development-oriented science faces various obstacles. For example, many researchers show a poor ability to establish connections with other disciplines, and most of them are not prepared to face failures in multidisciplinary projects and even less to share these failures with their colleagues in a collective fashion. The lack of democracy within the research groups and absence of previous agreement in the definition of individual roles in research projects is a common factor of failure.

Most research institutions are structured and organized in a way that hinders interdisciplinary work and does not favour links with other sectors of society. There is often an absence of political will to promote scientific research activities aimed at sustainable development, which is considered to be a result of the lack of scientific culture among politicians and society at large.

The established policy of promotion, career development and assessment of researchers, as well as of their projects, is far from stimulating interdisciplinarity and development-oriented research. Present assessment systems are highly demanding in terms of scientific productivity (measured by published papers) and do not place any value on activities of social analysis and development, thus resulting in many researchers being concerned for their personal production and disconnected from societal concerns.

There is, among those scientists involved in sustainable development projects, a widespread frustration with existing large-scale funding mechanisms, their associated patronage and short-term focus on donor-defined results.

Recommendations

In order to overcome the drawbacks, with existing systems a number of actions can be undertaken, including the following:

- The creation of mechanisms that foster and legitimise interdisciplinary work, in particular by financing research projects that bring together multidisciplinary teams for addressing real problems, and launching initiatives that call for interdisciplinary research.
- Researchers and university students need to be trained in working with communities, while at the same time other sectors of society should be induced to recognize the value of scientific contributions to sustainable development.
- In assessing the performance of researchers, it is important that the work in the field of sustainable development be evaluated by referees who themselves have an interdisciplinary perspective and who are prepared to consider the value of scientific activity that is not purely academic but is related to socially relevant issues and includes a component of community-related work.
- All governments should develop a basic agenda for sustainable development and stimulate financing agencies to invest in line with this agenda. It is important to devote resources to projects having long-term objectives; the funding should cover the various phases of the project. Decentralised planning is necessary, to take into account the needs and orientations on a local and regional basis.
- International funding agencies should give definite and decisive support to public higher education and research institutions in developing countries, in order to increase and strengthen their capacity for education and research in general, and in the field of sustainable development in particular.
- Efforts should be made to utilize local scientists and communities in project leadership, with assistance provided by those from outside the community in facilitating, catalysing and supporting such activity.
- Longer funding cycles are much more appropriate for sustainable initiatives. New solutions (e.g. autonomous funds) are needed to move toward a relationship of joint ownership and decision-making among the various stakeholders.
- Research of high quality and relevance related to sustainable development, especially that carried out in developing countries, should be recognized in specific ways, for instance through the granting of international awards, nomination to international committees, etc.
- It is interesting to note the bias towards sustainable development activities in rural areas, despite the unprecedented process of urbanization and concomitant de-ruralization that has taken place in recent decades, and that will clearly continue in the near future. In view of this trend, the national research and higher-education systems should incorporate the sustainable urban development theme in their agenda.

Box 3: Capacity building for sustainable development in Mexico

Neither socio-economic conditions nor the state of the environment have improved globally in Latin America in the last ten years, and the corrective measures implemented have been clearly insufficient to reverse the negative trends. A recent comprehensive diagnosis points to severe environmental degradation, including loss of biodiversity, soil erosion, massive loss of native forests, fresh-water depletion, and pollution of rivers. The causes for this degradation are multiple, and call for a complex, multidimensional strategy for their solution - a strategy that has to incorporate the fact that the sustainable development of the region depends increasingly on factors lying outside the control of the region itself.

On the other hand, some positive changes that have taken place in the region are worth attention, in particular the gradual process of political democratisation -essential for a good outcome of sustainable development efforts- and a certain accumulation of positive experiences with sustainable development projects.

Although important work on ecosystems and environmental problems was initiated in a few universities and research centres already in the 1970s, the last decade has witnessed some notable developments in this field. Below are listed some public research institutions in Mexico, with special focus on the capacity-development aspects. Since the choice had to be a limited one, far from pretending to be comprehensive, we restrict ourselves to illustrating some particularly relevant experiences with centres that have already built a tradition in this field.

- *Department of Ecology of Natural Resources, Institute of Ecology, UNAM. Morelia, Michoacan.*
  This Department carries out interdisciplinary work with important social projection, in various basic and applied areas of ecology, with the purpose of providing socially, economically and ecologically viable alternatives for the peasant communities as well as norms for the local and federal government sector. It is planning to set up a Centre for Research on Ecosystem Management, with the purpose of carrying out research and higher education from a truly interdisciplinary perspective including the social-sciences component and establishing close links with the various sectors of society.

- *Institute of Ecology, Jalapa, Veracruz.*
  This Institute carries out research and higher education in the areas of biodiversity, conservation and systematics, aimed at the rational use of ecosystems through a better knowledge of the mechanisms and processes taking place rather than of the species themselves. Projects include multidisciplinary activities involving ecology, economics, systematics, social psychology, sociology and anthropology. The Institute was pioneer in the creation of Biosphere Reserves, where the inhabitants are involved in conservation activities. Social agreements are fostered among the productive sectors having a stake in the Biosphere resources, thus contributing to solve conflicts of interest.

- *The College of the South Border (ECOSUR), Chiapas.*
  This research centre is located in a zone of major social conflict, in the South of Mexico. The concept of sustainable development sets the basis for both research and higher education (with a masters degree in Natural Resources and a doctorate degree in Ecology and sustainable development), including the productive, social and biodiversity components, and involving economics, anthropology, sociology, medicine, political sciences, ecology, agronomy, and biochemistry. The research work places emphasis on the limitations to the increase in primary production in the rural environment, the challenges for sustainability, and the use and conservation of biodiversity. It has mechanisms for communication, integration and permanent exchange of knowledge, technologies and research experiences with the various sectors of local society.

- *Centre for Atmospheric Sciences, UNAM, Mexico City.*
  Much of the work at this Centre is oriented to the study of possible consequences of climate change, with the necessary involvement of physics, geography, biology, sociology, economics and international relations. A significant interface with society is achieved in a study on the adaptability of social sectors to climate change, their vulnerability, and viable options involving preservation of natural resources and economic foresight. The graduate programme in Earth Sciences is multidisciplinary to a certain extent, depending on the specific topic chosen by the student.

In addition to the regular budget provided by the government, these institutions receive special funding for projects from various national and international sources, notably from the Packard Foundation, the Mac Arthur Foundation, the Ford Foundation, the Rockefeller Foundation, the National Inst. of Health, the Environmental Protection Agency, the Department of Agriculture and the Fish and Wildlife Service (USA), as well as from the European Union, the Spanish Cooperation Agency, UNIDO, UNDP, UNEP, the GEF and the World Bank.

International Cooperation

While the need to promote scientific capacity building applies to all countries, we must also recognize that the gap in science and technology capacity between countries in the North and the South is growing larger, not smaller. In fact, science and technology capacities are even more concentrated than economic resources. North America, Europe, Japan & Asian newly-industrialised countries produce 60 per cent of world's gross national product, and are responsible for 85 per cent of world expenditure in science and technology, even though they represent less than 25 per cent of the world's population. In contrast, China, Latin America, and India account for a further 10 per cent of world spending on research and development, and Sub-Saharan Africa only 0.5 per cent.

Recent trends suggest that such disparities will increase. Yet, neither the North – because it is composed of countries with different performance levels and thus has its own "internal South" – nor the South can be seen as a homogeneous entity. Some countries in the South, the so-called "emerging countries", are in the process of outperforming several countries in the North, both technologically and economically.

The recent crises that struck many countries in Asia and Latin America, however, remind us that the prevailing situation may not last forever. Furthermore, issues related to the size of the country and the critical mass of its scientific communities also must be considered. Strategies for sub-continents such as India and China, whose scientific output and community are almost as large as that of all the other countries of the South combined, cannot be the same as strategies for other countries of the South with less than a million inhabitants and only a handful of scientists.

Researchers from the scientifically more advanced countries can benefit fully from collaborative research programmes with the North. Scientists from the North are especially willing to join such enterprises if their partners from the South are scientifically prominent. But for many other countries of the South, this approach can only be effective if combined with support measures that contribute to local capacity building. This means: training (or supplementary training) in research; institutional support that usually takes time (procuring laboratory equipment, supplies, scientific journals, etc.); tools for communications and networking, assistance in organising conferences; support for local scientific organisations and all other types of assistance that can contribute to building up research groups and local scientific communities.

North to South collaboration

As emphasized throughout this document, collaboration not only across disciplines but also across geographic borders, is an important component of science capacity building.

While North-South scientific cooperation is as timely as it was 30, 20 or 10 years ago, the context and the terms of the debate about the value of such cooperation have changed considerably. As a result, fresh thought needs to be given to the basis of scientific cooperation and research support policies, fields of intervention, organisational models, and the terms and conditions of "aid" and cooperation.

Based on several decades of experiences of North-South S&T cooperation, a number of lessons have been learned. Conditions for potential successful North-South S&T cooperation can be summarized as follows:

- Projects should have clearly enunciated and verifiable goals;
- A critical mass of resources, strategic partnerships and long-term commitments should be nurtured and maintained.
- Systemic approaches and follow-through support for science, technology, innovation and policy should be pursued.

- Systemic approach involving the different stakeholders, including policy makers, should be a priority;
- Research should be embedded in a larger context of policy development emphasizing poverty alleviation and equity.
- Priority setting, agenda formulation, research collaboration and decision-making should be based on full and real participation of the South.
- Priority setting should start at the local level through partnerships with community-based organizations.

Working together, scientists from the North and South should rely on their diversity to bring new problems to light and to formulate new research goals. Such a strategy would not only benefit society but also enrich science itself.

These efforts, however, are made complicated by the unequal distribution of research resources. To compensate for this problem of worldwide asymmetry, the tools of cooperation and partnership must be complemented by research-support tools for local capacity-building that spur the formation of dynamic and sustainable national scientific communities.

South to South collaboration

Efforts to promote South-South cooperation may be more important now than ever before and, as a result, such efforts must be pursued with more vigour and determination. Indeed South-South cooperation has in many instances proven to be the most effective way of creating a critical mass of highly qualified and innovative scientists and technologists in the South who are trained to address issues of critical importance to the people who live there. These efforts, moreover, can represent the clearest path to developing a professional culture of scientific excellence comprised not of expatriate scientists, who make their mark abroad, but of scientists who remain at home where their contributions are most needed.

The fact is that talented and innovative local and regional scientists are needed to make a difference in the lives of the hundreds of millions of impoverished people living in the developing world; and educational and training strategies, based on South-South cooperation, can help build an enduring framework that encourages the developing world's most talented scientists to stay at home. Such strategies are likely to be the most cost-effective, lean most heavily on issues of prime importance to the South, and carry the added benefit of building self-esteem and self-confidence both on an individual and institutional level.

As governments provide additional resources for building scientific and technical capacities within their own nations, scientists, in turn, must display greater enthusiasm and commitment for using their knowledge and skills to address practical problems. That is why some of the most significant partnerships in South-South cooperation must be forged around such issues as food security, water management, genetic engineering, use and conservation of natural resources, protection and restoration of biodiversity. It is also why highlighting "best practices" in the use of science for sustainable development in the South is such a critical exercise. And that is why scientists must work more closely with their governments in devising research strategies that represent not just good science but science that is good for their societies.

Science must be part of the quality equation, especially in nations throughout the developing world with intractable problems that adversely affect the everyday lives of a majority of their citizens. Such a strategy should be part of a "new contract" between the scientists of the developing world and the countries in which they live and work – a contract in which the government agrees to provide reliable and sustained financial support for scientific research in exchange for the scientific community's willingness to use their knowledge and skills to address their nation's most pressing social and economic concerns. Such efforts will help overcome the isolation that has traditionally plagued scientists in the developing world by nurturing fruitful partnerships among scientists that have much in common and who work in nations that share many of the same problems.

What accounts for the steady growth in South-South partnerships in science and technology over the past two decades? There are three fundamental forces driving these trends. First and foremost, there has been a marked increase in the commitment that at least some nations in the South are making to science and technology capacity building. Second, there has been a rethinking among funding agencies in the North on how best to achieve long-term results through the direct participation of Southern institutions in the plan-

***Box 4:** South to South Partnerships in Capacity Building*

When the Third World Academy of Sciences (TWAS) launched its South-South fellowship programme in 1986 as one of its first programmes, it was virtually alone in such efforts. That year, a total of 18 grants were given to young researchers. Since then, TWAS, through its own efforts and in partnership with others, has been at the centre of a number of "fellowship" initiatives designed to build scientific capacity in developing nations through South-South cooperation. For example, working with India's Council of Scientific and Industrial Research (CSIR), TWAS oversees a post-graduate and postdoctoral fellowship programme based on the same principles as its original fellowship programme.

With funding from the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the OPEC Fund for International Development, TWAS also oversees a South-South associateship scheme designed for mid-career researchers to visit centres excellence in the South. And this year, TWAS has launched a programme enabling recently minted PhDs to receive postdoctoral training in universities and research institutions in the developing world.

But unlike in the mid 1980s, TWAS has been now joined by a growing number of organizations – both international and bilateral – that pursue the goal of scientific capacity building through a broad range of South-South cooperative strategies. Examples include:

The Third World Network of Scientific Organizations (TWNSO), a group of science ministries and research councils dedicated to promoting political and scientific leadership in the South with the aim of advancing science-based sustainable development, was established in 1988, and now has more than 150 members. Working closely with the ministries of science and technology, TWNSO has been instrumental in raising the profile of scientific research in policy circles in Brazil, China and Iran, for example.

Another body is the Third World Organization of Women in Science (TWOWS), a global network dedicated to promoting the role of women in scientific and technological research and development. Its membership, which has grown steadily since the organization's inception in 1993, currently consists of more than 2000 scientists, the majority of whom are women scientists living in developing countries. The centrepiece of TWOWS's activities is a post-graduate South-South training programme for young women scientists from sub-Saharan Africa and least-developed countries. The programme involves some 70 institutions in the developing world. To date, more than 150 young women scientists have been assisted by the programme in a wide variety of fields in biology, chemistry, mathematics and physics.

The China-Brazil Earth Resources Satellite (CBERS) programme, designed to develop joint earth-resource monitoring satellites, successfully placed its first satellite in orbit in 1999; a second satellite is scheduled for launch in August 2002. The programme, which involves bilateral cooperation in the development and use of satellite technologies and state-of-the-art remote-sensing analysis, has not only provided practical training but has also helped to raise levels of knowledge on a wide range of issues, including the spread of desertification and environmental pollution.

The African Centre for Technological Studies (ACTS) in Nairobi, Kenya, was created in 1988 to conduct in-depth policy research and contribute to the creation of knowledge necessary for Africa's development. ACTS has emerged as one of Africa's most prominent "think tanks" in the interrelated field of science, technology and development.

Comite Regional de Recursos Hidr licos/Sistema de la Integracion Centroamericana (CRRH/SICA), located in Costa Rica has developed a virtual climate centre that takes advantage of the tools provided by the internet and advanced information technologies to supply up-to-date climate and weather forecast information and services throughout the seven-nation Central American region.

ning and implementation of projects. And third, there has been increasing global emphasis on the importance of science-based sustainable development as the basis of a more prosperous, secure and equitable world.

On the first front, successful South-South partnerships in science and technology – and the social and economic benefits derived from such efforts – have been due to sustained investments in science and technology made by individual governments. Over the past several decades, such investments have helped to build a critical mass of scientific expertise and have led to the construction of some excellent research facilities across all regions. As a result, scientists from the South can now receive excellent instruction and training in universities and research institutions by enrolling in universities in the South. The instruction that students are receiving in many developing-world institutions now represents a quantum leap forward in quality compared to the level of instruction that they were receiving a decade or two ago. Equally important, both the number of quality institutions and the overall quality of their instruction are steadily increasing.

The lesson here is that South-South cooperation must rely on strong and enduring national commitments to scientific and technological capacity building. Put another way, there can be no successful bilateral cooperation without sustained unilateral investments in science and technology beginning with education at the primary level and continuing through post-graduate studies.

On the second front, the increased emphasis that Northern funding agencies and foundations have placed on individual and institutional capacity building in science and technology has helped bolster the efforts of governments in developing countries to pursue like-minded strategies. Here the Nordic countries, led by Sweden's Sida-SAREC, have forged new strategies for advancing education and training among young scientists in the South. These strategies are designed to encourage young scientists to remain in their home countries once they have earned their degrees. For example, the so-called "sandwich programme", which requires students to enrol and receive their degrees from universities in the South while, at the same time, providing opportunities for them to visit universities in the North during the course of their studies, is intended to keep students in touch with their own countries and thus to become more likely to pursue their careers at home.

Each of these efforts is in the early stages of implementation. As a result, we will not be able to gauge their full impact for some time. Nevertheless, the strategies behind these efforts suggest that we have developed, at last, a new paradigm in scientific partnerships. This paradigm, which emphasizes both individual and institutional capacity building, seeks to have Southern partners play central roles both in defining the nature of the problem and in proposing possible solutions. Moreover, it ultimately measures success on the ability of the programmes to become self-organizing and self-sustaining over time.

Recommendations

The following recommendations would not only help strengthen North-South cooperation, but would have the added benefit of strengthening South-South cooperation by helping to enlarge the network of scientific centres of excellence in the developing world that could then work together:

- Support for proposals to build international scientific research centres in developing countries that focus on such critical issues as tropical diseases, renewable energies, biotechnology, and information and communication technologies. These efforts should explore both the possibility of upgrading competent national and regional centres and creating entirely new centres in the absence of existing institutions that have displayed the capacity to grow and improve.

- Support for international science programmes to incorporate capacity building in the South into their core activities. Such efforts, which have become central to the Intergovernmental Panel on Climate Change (IPCC), the Millennium Ecosystem Assessment, and the collaborative work of the Initiative for Science and Technology for Sustainable Development, TWAS and ICSU, should be adopted by all other international science and technology initiatives.

- Continued support for the creation and strengthening of international and regional networks of science academies taking place, for example, through the InterAcademy Panel on International Issues (IAP), the Association of Academy of Sciences in Asia (AASA), the All European Academies (ALLEA) and Caribbean Scientific Union.

- Mobilization of expatriate third world scientists living and working in the North to examine critical problems in developing countries together with their colleagues in the South, and to assist in building the capacity and excellence of scientific institutions in the developing world. Such efforts could prove instrumental in turning the brain drain into a brain gain.

To specifically advance South-South cooperation, we propose the following strategy:

- Increased support for undergraduate, graduate and postgraduate South-South fellowship programmes devoted to quality education in science and technology. These programmes should utilize the best research and training centres in the South to attract and train the developing world's most talented students.

- Continued development of South-South institutional networks to share innovative experiences and address critical economic, environmental, public health and social problems. Such institutions should pursue joint problem-solving research activities and devote the time and resources necessary to describe and discuss their experiences with others both within and beyond the scientific community. In trying to increase the relevance of their research projects they should seek to draw on the knowledge of local communities in the areas related to sustainable development.

- Forging stronger links between the South's scientific communities and the South's political institutions. In addition to the WSSD , the Group of 77's first conference in science and technology, scheduled for later this year, represents an important upcoming opportunity for strengthening and extending the ties between science and society.

Science Communication for Sustainable Development

"Improved communication and cooperation between the scientific and technological community and decision makers will facilitate greater use of scientific and technical information and knowledge in policies and programme implementation."

This statement, from Chapter 31 of Agenda 21, neatly sets the scene for discussing the importance of science communication in the context of promoting sustainable development. Not only does it highlight the need to ensure that scientific information gets into the hands of those taking decisions, but it also emphasizes that the reason for this is the ensure that such decisions are properly informed.

Decision-making in a democracy is a complex process, involving constant interaction and feedback between elected officials, government administrators, non-governmental organizations and the scientific community. It must also involve the public that must both be allowed to participate in such debates, to influence their outcome, and ultimately endorse any final decision through the ballot box.

It is important, therefore, to keep this broad conception of decision-making in mind both in promoting the need for an enhanced communication of science in the interests of sustainable development, and in drafting concrete proposals for action that will achieve this through capacity building steps.

Science communication as a multi-actor process

We need to start by acknowledging that science communication not an isolated practice that can be left to a body of professional 'science communicators' but a multi-actor process, achieved through a range of formal and informal channels. The process starts with the scientist at one end, and finishes with the decision-maker or the public at the other. But it is also a process that is implemented and influenced by numerous other groups along the way.

In other words, there are various channels through which "scientific knowledge" travels from the laboratory bench (or field experiment) to the decision-makers desk. One of our tasks should be to identify the various groups involved in this process; these can include scientists, public information officers, science journalists, those responsible for science centres and museums, and policy analysts, as well as those administrators and decision-makers who act as the primary recipients of scientific information.

It is important to understand the different functions that each group plays in the overall process of science communication. Once we have done this, it should be possible to identify how each of these groups can perform this function more effectively – this, surely, is the meaning of the term 'capacity building'.

There is not a single set of needs common to all the groups involved in communicating science. Rather, it is important to look at the function, responsibilities and needs of the different professional groups within this overall process. We should also remember that each professional group is working to an agenda in which the effective communication of scientific knowledge is only one component.

A professional journalist, for example, is not only concerned about reporting science accurately. He or she, whether working in a print medium, in television or in radio – a particularly important form of communication in developing countries – also has to generate the interest of readers, viewers or listeners. Just as important is meeting the requirements of news editors, and ultimately either government sponsors (for publicly owned media) or the financial goals of proprietors and shareholders (for those media outlets that are in private hands).

Meeting this second set of responsibilities can mean following rules of 'good journalism' that are not necessarily approved of by those whose activities are being reported on (for example, if they would prefer, for commercial or other reasons, that such information be kept confidential or out of the public eye).

A science public information officer, on the other hand, has a different agenda. One dimension is to portray an accurate picture of the work that is carried out inside an institution. But another equally important task is to promote a particular image of that institution through the press. In practice, this means attempting to boost the positive aspects of this image, and dampen (if not suppress) the more negative components. This can, in certain circumstances, mean that the professional task of the public information officer is to impede the professional functioning of a science journalist.

In a different field, those responsible for science centres or science and technology museums have a primary responsibility - like the other professional groups – to communicate science accurately and intelligibly to the public. But they also need to attract visitors through their doors, as well, in practice, as present an image of science or technology that fits the conceptions of their sponsors.

Similar qualifications need to be made about each of the separate groups involved in the process of science communication described above. Scientists may be keen to inform policy-makers about their research; but they are also concerned with their professional standing, and with their own funding prospects (one reason frequently given why many are reluctant to be seen to be talking directly to the public). Press coverage that might damage either of these (for example, by making it more difficult for results to be accepted by a scientific journal) is usually unwelcome.

Similarly, policy institutes tend to incorporate recommendations that include scientific knowledge within broader strategic proposals. And politicians, of course, always have an eye on their future electoral prospects when deciding what elements of science to take into their decisions - in other words, which scientists to be seen to be listening to (think about President Bush and his position on the science of climate change, or the UK's attitude to Bovine Spongiform Encephalitis - BSE - in the early 1990s).

Any recommendations about enhancing the capability of countries - and developing countries in particularly - to communicate science effectively must therefore be done in a way that is profession-specific. In other words, it must take into account both differentiated (and sometimes conflicting) responsibilities, and differentiated constraints.

For example, addressing the role of science journalists in communicating science responsibly and effectively requires addressing the practical hurdles that they face in achieving this task. These range from a lack of resources, training or appropriate professional skills to broader issues such as public perceptions of significant news, as mediated through the judgements of news editors and newspaper proprietors. Capacity building is the task of empowering an individual journalist to tackle these hurdles effectively, and the same is true for public information officers – indeed for each of the professional groups identified above.

The sustainability dimension

An additional challenge is created by the requirement to embrace a commitment to the concept of sustainable development. If this means anything in operational terms, it is that the global community should continue to take steps to promote social and economic development, and stop doing things that undermine the long-term ability of the planet to support both processes. Enhancing the contribution of science to such a desirable goal can only be endorsed.

Although such principles are easy enough to state, however, they create major dilemmas when putting them into practice, particularly when it comes to science communication. Is a public information officer who promotes the benefits of genetically engineered foodstuffs promoting sustainable development by offering a way of tackling widespread hunger? Or exacerbating the problem by justifying irreversible human intervention into the evolution of our natural environment?

Similarly is the journalist who writes uncritically about the benefits of nuclear power as a potential source of relatively clean, renewable energy promoting sustainable development? Or is he or she or undermining it, perhaps by ignoring or downplaying the issue of long-term disposal of radioactive waste?

We face a dilemma. Science communication plays a critical role in sustainable development, and we therefore need to enhance the capabilities of all those responsible for fulfilling this role. At the same time, we need to address whether the professional requirements placed on such individuals are in any way different from the requirements placed on those already engaged in science communication, but with no particular concern about the wider picture. And if so, how.

The response to this has two parts. Firstly, each group has developed a set of professional skills that need to be respected as the most effective way of meeting its social and professional responsibilities. These skills have developed over many years, often under close public scrutiny. In other words, the skills required of a good 'science for sustainable development' journalist, working in any medium, are identical to the skills required of any competent science journalist in that medium.

Similarly the skills required of a good public information officer remain constant, whether or not he or she is practicing these skills within the context of a commitment to sustainable development. And the skills required on a competent science museum curator remain important.

The second part of the answer relates to how these skills are exercised. Here it is important to stress the way in which the main concerns of sustainable development – always remembering its three distinct pillars, the economic, social and environmental – need to 'inform' the way in which professional tasks are carried out. We should not attempt to lay down strict rules that determine how a professional task is carried out in order to conform to needs and goals of sustainable development. But we do need to develop ways in which reliable information about and a commitment to the concept of sustainable development are continuously held in mind.

The word 'inform' is deliberately used here to echo the debate about the relationship between science and policymakers, and in particular how it is often said that science needs to 'inform' political decision-making at all levels. It would be both wrong and unrealistic, given the multi-faceted nature of political decisions, that these should ever be determined by science in a rigid manner; at the end of the day, at least in any democracy, such decisions depend on social, not scientific, judgements. But it is also reasonable to demand, as many do, that science should 'inform' decision making, which essentially means that political decisions should be consistent with the best scientific knowledge available. This concept can be used in reverse. Namely, the practice of science communication (which, on a day-to-day basis, involves a host of decisions, both large and small) should be 'informed' by the concerns of sustainable development.

This does not mean that the professional decisions taken by those engaged in the various aspects of this practice – for example, over which stories to write, what approach to take in presenting a specific issue, or which experts or stakeholders to consult (and therefore legitimise by quoting their points of view in an uncritical way) – can, or should, be rigidly determined by such concerns. But it does mean that such decisions need to be consistent with the best available knowledge (social, economic, scientific and political) about which forms of development are sustainable, and which are not.

Indeed, perhaps the same approach needs to be invoked for the practice of science itself. There is widespread acknowledgement, as indicated above, of the need for science to inform political-decision making, including decisions made about sustainable development. This idea can also be reversed. Rather than demand a new type of science to promote sustainability, our goal should be to ensure that the professional practice of all forms of science is adequately 'informed by' the concerns and goals of sustainable development.

General principles

Where does this lead in practice? Here we set out a list of general principles about the needs that exist for enhancing capacity in science communication (particularly in developing countries):

Firstly, there is a clear need to promote capacity building – for example through workshops and training courses – in three separate areas:

- communication skills for scientists, to enable them to interact effectively with communications professionals (some examples here are provided by the AAAS Mass Media Science and Engineering Fellows programme);
- professional skills for public information officers, to help

them communicate information effectively about the work of scientists and its significant;

- comparable skills for journalists to help them to write accurately and effectively about science and science-related issues (which requires some basic knowledge about science, but not necessarily a deep scientific background);

- professional skills for those who run science centres or science museums in how to construct exhibitions that effectively engage and communicate with the public.

Secondly, science journalism, particularly in a development context should not be restricted to writing about 'science' in a narrow sense, but conceived as an form of journalism that covers the scientific aspects of issues arising in the fields of health, environment, agriculture and food production, and energy. In consequence, improving the quality of science communication in many countries should focus on increasing the number of professional journalists able to write knowledgably about science as it bears on these fields, rather than specifically developing a corps of dedicated science journalists;

A major challenge in achieving this goal is to convince newspapers – which in practice means convincing the editors, managing editors and news editors who act as 'gatekeepers' to what is considered newsworthy – to allocate more space to science-based stories around such topics, and therefore to acknowledge the importance of the scientific aspects of such issues;

At the same time, scientists need to accept that, in order to enhance the overall process of science communication in its broadest sense, one of their professional responsibilities should be to make themselves more directly available to journalists (and by implication, more accountable to the general public).

Recommendations

The following practical steps are proposed as ways of building capacity in science communication, particularly in developing countries:

- Organising workshops on a national or regional basis at which each of the four groups listed above can develop their professional skills (an example here is the recent workshop organised in Tobago jointly by SciDev.Net and the InterAcademy Panel);
- Preparing a series of short 'field guides' that provide a summary of best practice in each profession.
- Preparing regional (and perhaps international) databases of the names of individuals involved in each aspect of the communication of science. This would include, inter alia:
  a. a list of scientific experts in different countries willing to engage in direct communication with journalists;
  b. a list of science information officers and others responsible for communicating information about science within their respective research institutions;
- A list of journalists committed to writing about science-related issues in an informed manner.
- Organising and supporting regional associations and networks of individuals engaged in each of these four fields, allowing them to communicate and interact both within their respective professions, and between professions;
- Encouraging the publication of popular books and magazines devoted to informing the public about key scientific developments and helping them to become sufficiently informed about science-related issues to participate effectively in debates on these issues;
- Exploring other forms of science communication, for example through theatre productions that engage audiences in active debate about key science-related issues.
- Encouraging professionals experienced in the communication of science, whether as journalists, communications officers, museums curators, or even theatre directors, to act as personal 'mentors' to individuals at the start of their career.
- Ensure that an introduction to the goals and concerns of sustainable development – and of the potential contribution of science and technology to these goals, as well as actual and potential conflicts – is incorporated into the formal and informal training received by all those professionally committed to participating in the communication of science.
- Prepare concise, readable material, that can be circulated either in written form or electronically, directed explicitly at the professional needs and interest of all those engaged in science communication, that summarises the potential contributions of science to sustainable development (for example, in the fields of health, agriculture).

Annex

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